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Program Analysis
and Planning for
Phase C/D
Document

Volume 7

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Atmospheric, Magnetospheric and Plasmas in Space (AMPS) Spacelab Payload Definition Study

MARTIN MARIETTA

Bendix

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ATMOSPHERIC, MAGNETOSPHERIC AND PLASMAS IN SPACE (AMPS) SPACELAB PAYLOAD DEFINITION STUDY

Prepared for

Goddard Space Flight Center
Greenbelt, Maryland 20771

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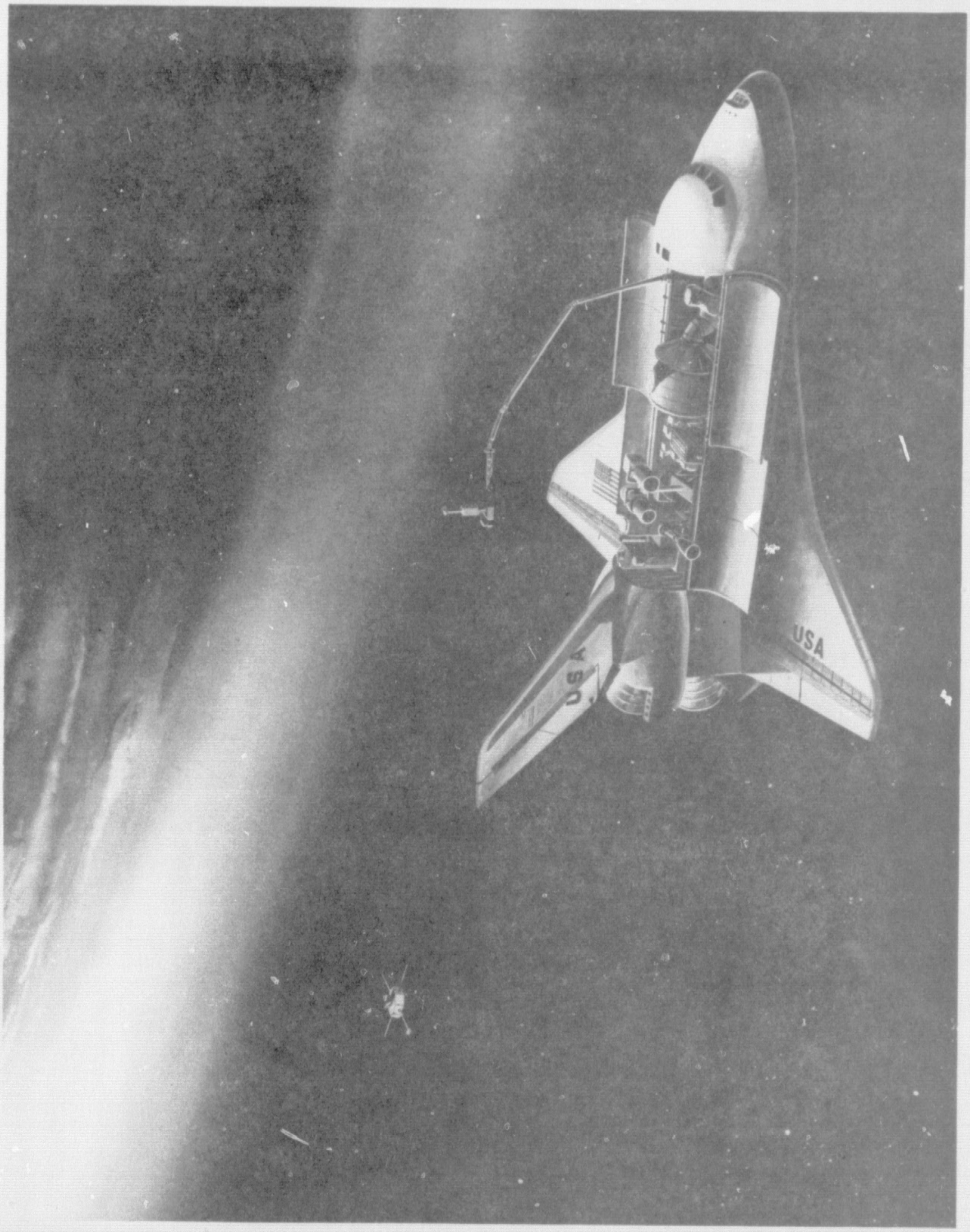

Frontispiece

FOREWORD

The AMPS final report is submitted by Martin Marietta in accordance with Data Procurement Document Number 486, Revision A, of Goddard Space Flight Center Contract NAS8-31689.

The AMPS final report consists of seven volumes. They are:

Volume 1	DR MA-05-A	Executive Summary Report
Volume 2	DR SE-01-A	Mission Support Requirements Document
Volume 3	DR SE-02-A	Interface Control Documents
	Part 1	AMPS Payload to Shuttle ICD
	Part 2	AMPS Payload to Spacelab ICD
	Part 3	AMPS Payload to Instruments ICD
Volume 4	DR SE-03-A	Specifications
	Part 1	AMPS Program Specification
	Part 2	Labcraft Payload General Specification
	Part 3	Labcraft Instrument Systems General Specification
Volume 5	DR SE-04-A	Deleted per Paragraph I, Attachment A, Request for Proposal under Changes Clause, dated 8/31/76
Volume 6	DR SE-05-A	Instruments Functional Requirements Document
Volume 7	DR MA-04-A	Program Analysis and Planning for Phase C/D Document
Volume 8	DR MF 003R-A	Program Study Cost Estimates Document

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I PROGRAM SUMMARY

The Atmospheric, Magnetospheric and Plasmas in Space (AMPS) payload (a Labcraft Spacelab program) uses the capabilities of the Space Transportation System (STS) to provide an orbital national research laboratory for scientific investigations in these areas. The initial flight of the AMPS laboratory is targeted for 1981, with the program remaining operational during the decade of the '80s.

The laboratory uses coordinated instrument groups, complemented by flight and ground support equipment, to study the earth's near-space environment and solar/terrestrial physics. Investigation modes will include the use of large aperture remote sensing instruments; in-situ diagnostic sensors; active perturbation experiments; and separated instrument platforms on sub-satellites.

The laboratory can support the use of instruments built for NASA by various American universities and contractors as well as by space research groups in other countries. The return-from-orbit capability provided by the STS introduces a new era that allows multiple reuse of the instruments and extension of the instruments' capabilities during the life of the program. This permits the development of an evolutionary science program that is both economical and responsive to changing requirements.

The AMPS program provides scientists with a short reaction time from experiment concept to implementation. During flight, the scientists on the ground and in orbit will be closely coupled in their investigations through the Goddard Space Flight Center (GSFC) Payload Operations Center (POC).

The AMPS program definition phase has been completed. Typical missions have been identified for AMPS flights in the early 1980s. Experiment objectives have been defined and typical scientific instruments selected to accomplish these objectives. Mission requirements have been defined and the Shuttle and Spacelab capabilities assessed to determine any AMPS unique requirements. Preliminary design concepts for the first two AMPS flights have been completed and form the basis for the Phase C/D program plan. This plan implements flights 1 and 2 and indicates how both the scientific and flight support hardware can be systematically evolved for future AMPS flights.

A. Science Program Definition

The AMPS Science Working Group (ASWG) developed the long term science objectives for the atmospheric, magnetospheric and plasma disciplines in the AMPS Science Objectives Document to provide the guidelines for the long term program evolution. Working with the ASWG and GSFC, Martin Marietta has developed a ten year, time phased schedule of priorities to guide our program definition and provide a focus for cost/capability trade-offs. The ten year program projection

provides a programmatic outline for the development of AMPS/Labcraft hardware elements that is keyed to the scientific priorities established by the ASWG.

Early flight emphasis is placed on the study of stratospheric chemistry phenomena so essential to understanding the impact of anthropogenic activities on the chemistry of the upper atmosphere. Similarly, in the magnetospheric disciplines, emphasis is placed on the study of parallel electric field interactions, and the understanding of high energy beam-plasma interactions.

The ASWG has defined a series of five typical missions to serve as a basis for the definition study (Figure I-1). These scientific missions address the study of the chemistry and dynamics of the stratosphere/mesosphere, the physical processes that couple the magnetosphere to the atmosphere, and the study of plasma processes. Specific experiments were designated for each of the five missions and their implementation was outlined by the ASWG through their definition of the experiment operational requirements and instrument functional requirements that satisfy the experiment and mission goals.

The first two missions of the five typical missions were selected by GSFC as the basis for this Phase C/D program plan.

The experiments for AMPS flights 1 and 2 include a series of remote sensing observations of minor constituents in the stratosphere/mesosphere; investigations employing active perturbations to study the role of electric fields, ionospheric conductivity and wave/particle interactions in magnetospheric/atmospheric coupling; and studies of plasma flows, beam plasma interactions and plasma wave generation. These investigations form the scientific requirements basis for this Phase C/D program plan.

B. Instrument Definition

Representative instruments to conduct the mission 1 experiments on the first AMPS flight are shown in Figure I-2.

The remote sensing instruments consist of a laser sounder, limb scanner, interforometer/spectrometer and near-IR spectrometer. These instruments make up a complementary group to measure the distribution of atmospheric minor constituents. The laser sounder is mounted in a fixed orientation on the aft pallet and is pointed to the nadir by the orbiter. The cryogenically cooled limb scanner is a far-IR radiometer mounted on a pointing platform along with the cryogenically cooled far-IR interferometer/spectrometer. The near-IR spectrometer is mounted on the second pointing platform on the forward pallet so that it can look at the sun during sunrise and sunset occultations.

Instruments used for active experiments in the first flight consist of the gas release modules, optical band imaging photometer

Goals \ Mission	1	2	3	4	5
Solar/ Terrestrial Relations					
Sun/Geomagnetic/ Weather Variations	Minor Const Mapping Gravity Wave Impact	Minor Const Mapping	Transport Effects on Minor Constituent Distribution	Transport Effects on Minor Constituent Distribution	Minor Const Distribution Variations (Solar Cycle)
Mag/Atm Coupling		Ionospheric Conductivity Study HF Wave/Particle Interactions	Ionospheric Conductivity Modification EIIB Source	E-Field Mapping	Conductivity Mod Effects
Plasma Astrophysics					
Solar System Plasma Flow Processes	Beam/Plasma Interactions Wake Studies	Plasma Interactions/Flows	Beam/ATM Interactions	Plasma Flow Processes	Field Aligned Current Gen V-Critical Study
Plasma Wave Radiative Mechanisms		Plasma Wave Generation	VLF Wave Generation	HF Plasma Wave Instabilities Beam Plasma Wave Generation	Plasma Beam Interactions Alfven Wave Generation

Figure I-1 Typical AMPS Missions

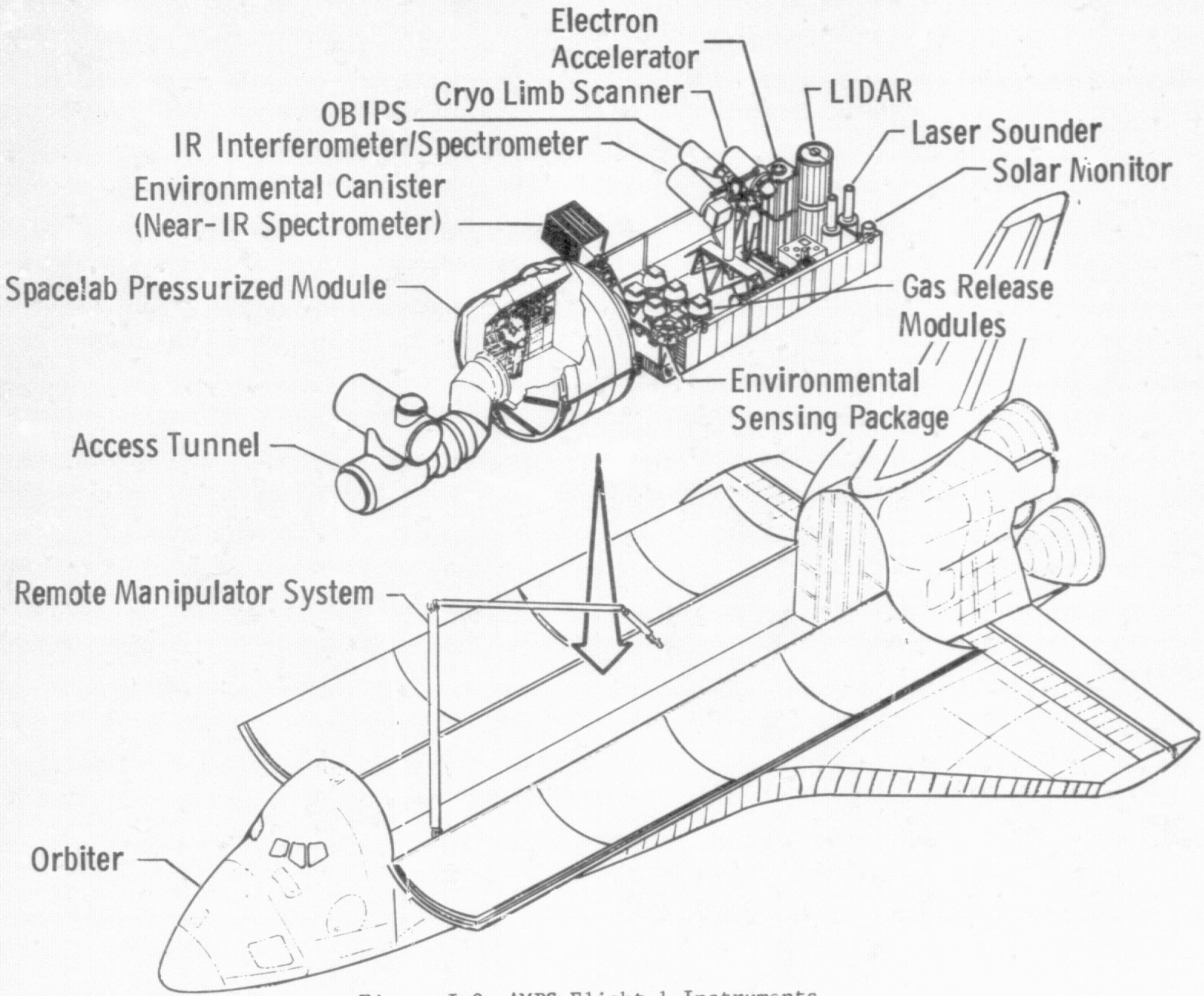


Figure I-2 AMPS Flight 1 Instruments

system (OBIPS), electron beam accelerator and beam diagnostics package. Six gas release modules, each containing 70 kilograms of nitrogen, and the low-light-level TV camera of the OBIPS are used to study acoustic gravity wave generation. The OBIPS is mounted on the third pointing platform located on the aft pallet. The electron beam accelerator is used in conjunction with the beam diagnostics package, which is deployed to its operating location by the orbiter remote manipulator system (RMS). The environmental sensing package (ESP), also deployed by the RMS, is used for electromagnetic interference and orbiter wake mapping. It is anticipated that several of these candidate instruments will have flown previously on earlier Shuttle flights and will have been refurbished and upgraded for these dedicated AMPS missions.

C. Flight Support Equipment (FSE) Development

As shown in Table I-1, most of the experiment/instrument support is provided by the Spacelab and orbiter, supplemented, where necessary, by AMPS unique flight support equipment.

The Spacelab pressurized module provides the laboratory area from which the experiments are conducted. The instruments are mounted on the Spacelab pallets using AMPS unique trusses and brackets. Environmental control is provided by the Spacelab, supplemented by a secondary cooling loop for the pallet-mounted equipment, i.e., a thermal curtain providing protection from solar heating.

The Spacelab provides electric power, supplemented by a high-voltage pulse power supply and a secondary power distribution system. For communication and data management, the Spacelab/STS capabilities are used, supplemented by a command and telemetry system for deployed instrument packages.

The orbiter is used to point instruments that are hard-mounted to the pallets and to control the direction of ejected devices. Pointing platforms provide instrument pointing and stability independent of the orbiter.

The RMS is used for instrument deployment. The FSE includes ejection devices and capture/release mechanisms. Emergency jettison capability for any equipment deployed outside the cargo bay is also provided.

D. Software Development/Integration

AMPS operational software is designed to use the full capability of the Spacelab and mission support data processing systems to enable the inflight and ground based science support teams to maximize the value of the data being collected for postflight analysis of the scientific community.

Table I-1 STS/Spacelab Role in AMPS

Subsystem	% Provided by Spacelab	Spacelab/STS Capability Used	New FSE Required
Structures	>60	Basic Mounting Hard Point Attach-ment	Secondary Trusses Brackets Deployed Device Structure Ejection Devices
Thermal Control -Module	Complete	Rack Air Cooling Compartment Control	None
-Pallet	>80	Coolant Loop Cold Plates Thermal Capacitor	Environmental Canisters (MMSE) Thermal Curtain LIDAR Loop Secondary Plumbing
APCS - Coarse - Fine	 >80 <50	Orbiter Pointing	Attitude Sensing MMSE Platforms SIPS, MPM
Electrical -Basic	>80	28 Vdc System Peaking Batteries	Secondary Distribution Deployed Device Power
-Conditioning	<50	400 Hz Inverter	HV Pulse Power
Communication	>80	Orbiter KU/S Bands TDRSS Ground Handling	Deployed Device Commands
Data Management	>80	Spacelab- Data Bus - RAU Computer Recording High Rate Mux Orbiter - Mux	Deployed Device Data Handling
Control & Display	>80	Keyboard - CRT	Manual Function Control Diagnostic Equipment
Deployment	>50	RMS	Deployment Devices

AMPS software must provide flexibility for the scientific crewmen in the relatively complex flight software package. To meet this objective, the software package is so designed that it is capable of relaying all experiment data to the ground while performing onboard sampling and presentation of only that data required for onboard evaluation.

The AMPS operational software program has been defined to meet the interfacing requirements of the flight and ground STS/Spacelab software efforts. The support sets that make up this AMPS software program are shown as highlighted blocks in Figure I-3. Five elements of activity are identified that span the operational regime from mission planning to the collection and management of real time mission data.

As shown if Figure I-3, the AMPS Mission Planning software provides integrated timeline and sequencing inputs based on fulfillment of the scientific mission objectives to the AMPS GSE checkout and computer loading software design. The Mission Planning software also provides the detailed mission timelines to AMPS Mission Operations software to identify trajectory, data management and command data link traffic.

The AMPS Mission Planning software also interacts with and provides inputs to the STS Mission Planning for long lead software requirements. AMPS experiment requirements are reflected in the requirements for the Spacelab Experiment Computer applications program. These programs, in conjunction with the onboard flight crew controls and displays and up-link commands, form the central control for all AMPS science operations.

The Orbiter Flight Computer will provide mission timing, caution and warning backup and orbiter attitude control and information. It also has some 10,000 words of core set aside for payload support. Individual AMPS experiments will incorporate processors to facilitate their required modes of operation, command and data transmission. The pointing platform stabilization systems are self-contained requiring only low data rates to the Spacelab Experiment Computer.

The array of AMPS flight software elements required for experiment support has been identified by analysis. These comprise an executive program, an array of real time computer modules, and an array of asynchronous modules. The asynchronous modules support the crew interface with the experiment and provide the crew with such services as experiment advisories, an automated time line and a plot/display capability. These programs can be controlled and modified from either the airborne keyboard or the ground. An interactive loop via the keyboard and display allows the crew to modify the course of the experiment.

This asynchronous approach is recommended because the experiment objectives do not require onboard processing of all data collected.

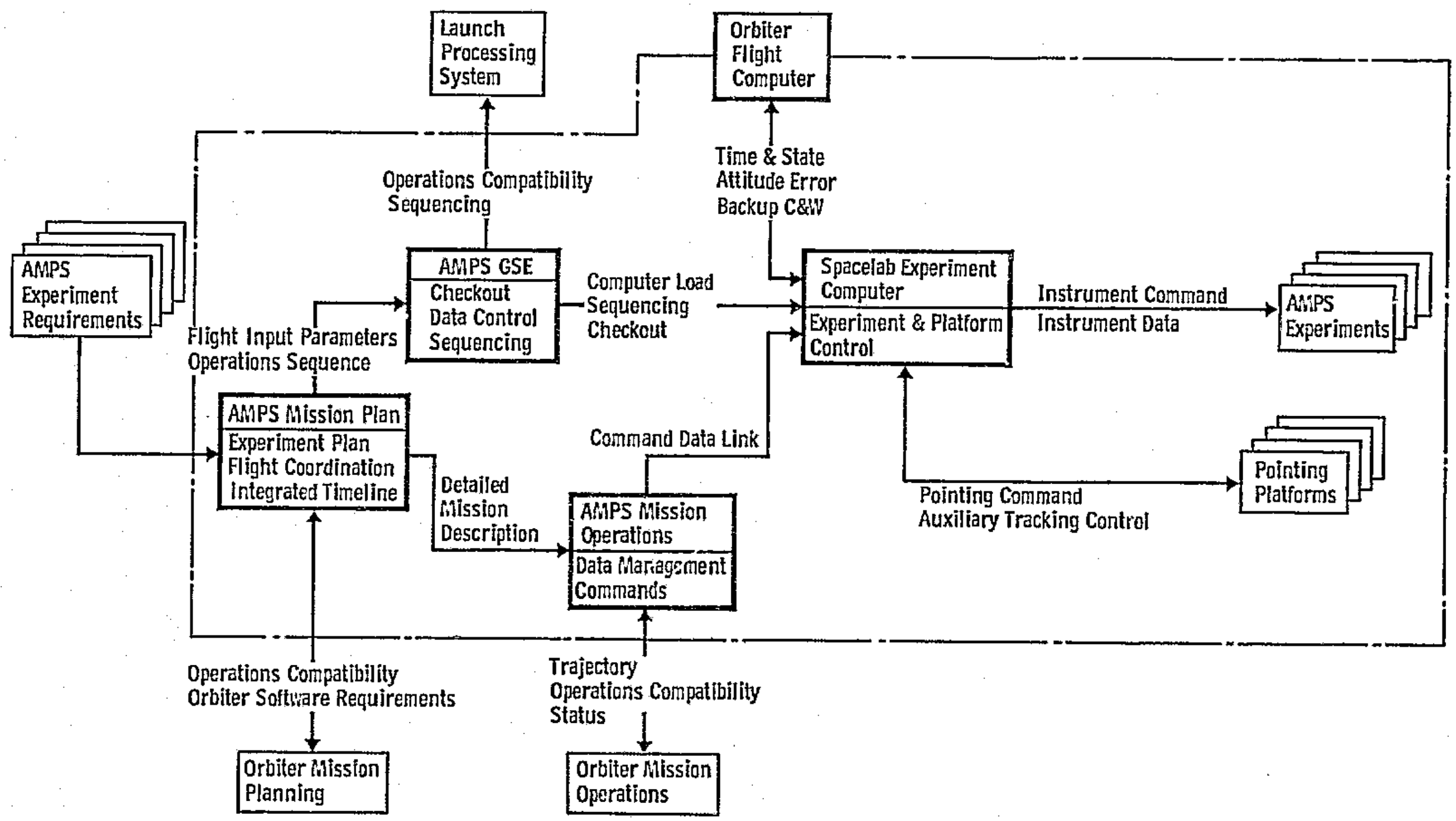


Figure I-3 AMPS Software Support Sets

Only the data sampling required to enable the onboard Payload Specialist to make experiment control decisions are processed. This system sends all experiment data to the ground in raw form for both real time and postflight processing but retains and operates only a limited sampling for onboard use.

Because this asynchronous software does not have to meet critical timing margins, the cost of developing the AMPS flight software will be held to a minimum. And because the ground-based software required to support AMPS flights is conventional, it, too, does not present significant developmental problems.

E. Payload Integration and Operations.

The AMPS dedicated Spacelab missions for the GSFC/Labcraft experimental program will be implemented using the capabilities of the STS/Spacelab flight and ground systems that will have reached operational capability prior to the initial 1981 flight. Figure I-4 shows the relationship of the Spacelab and STS elements, both spaceborne and ground, and their interrelationship with the AMPS/Labcraft program.

The GSFC AMPS payloads for STS/Spacelab will be formally established by NASA Hq direction to GSFC who will then acquire the AMPS/Labcraft prime contractor and proceed with the Phase C program definition. At the same time, the AMPS instrument contractors will be selected by AO awards and will initiate instrument system Phase B definition together with GSFC and the AMPS/Labcraft prime contractor to define instrument flight hardware, software and GSE. Other NASA centers may be asked to provide experiments for this mission and they will proceed under the direction of the OSS/GSFC mission managers to assure compatible payload integration.

The prime contractor effort will focus on the design and development of AMPS/Labcraft hardware and software that fulfills not only the special mission requirements of the first two flights but also GSFC's long term multiple discipline space science roles for astrophysics, solar physics and the continuing research in atmospherics, magnetospherics and plasmas. AMPS/Labcraft hardware and software for orbital operations will be developed in conjunction with ground and test support equipment which augments that already under development for the orbiter, Spacelab and multi-use mission support equipment (MMSE).

GSFC will draw on separately procured equipment such as the small instrument pointing system (SIPS) and other related hardware. FSE designed and built by the prime contractor will be combined with the SIPS and applicable MMSE on Spacelab flight pallets at the prime contractor's facility. If flight pallets are not available, then prime contractor supplied pallet simulators will be used. Instruments which have been pre-qualified by the GSFC instrument certification facility will then be integrated into the SIPS (or other pointing mounts), installed in racks, or mounted on the pallet substructures and finally assembled on the pallet simulators, cabled, and plumbed in with the FSE.

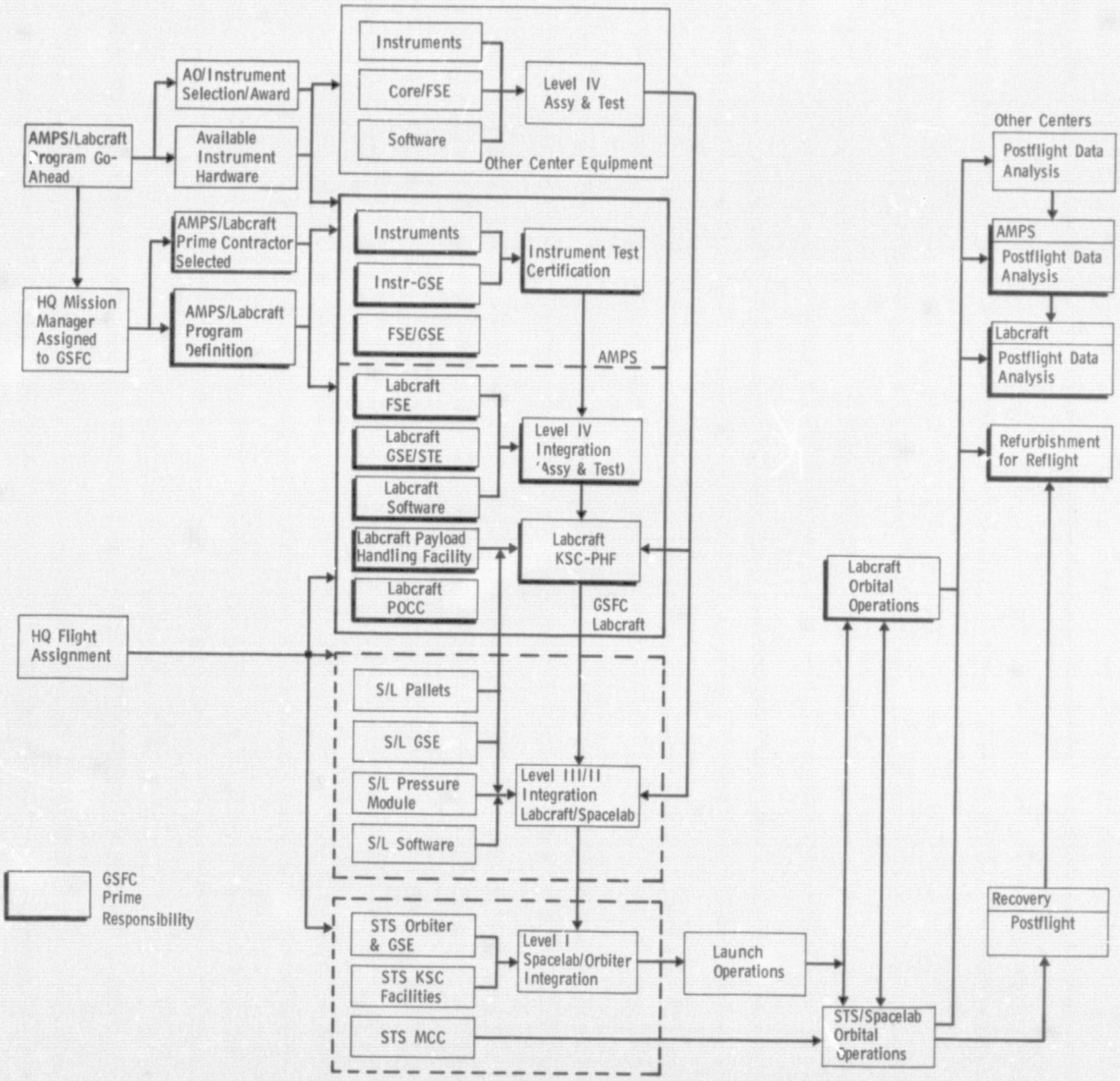


Figure I-4 AMPS/Labcraft Program Development Flow

During final assembly at the prime contractor's facility, the complete flight system will be checked out and tested using the GFP central 370 computer augmented with AMPS/Labcraft instrument and other required GSE/STE to verify safe hardware operation with the scientific application software and compatibility with the STS/Spacelab executive software. Both the flight and related ground software that will be used for later KSC integration and Level III, II and I testing will be initially verified during these prime contractor conducted Level IV operations.

The integrated, assembled flight pallets, or pallet simulators, and experiment racks with all installed flight equipment are then packed and shipped to the KSC AMPS/Labcraft off-line payload handling facility for final pre-delivery checkout and completion of Level IV integration.

After Level IV completion, GSFC hands over prime test responsibility from its prime contractor to the KSC Spacelab team and continues to actively support the STS/Spacelab on-line operations, particularly the systems tests and the simulated mission operations involving the flight crewmen. These tests will include the initial KSC/MCC/POCC interface tests for the flight hardware configuration and software verification.

Levels III and II testing proceeds to completion and the KSC Spacelab team hands over prime test responsibility to the STS operations team with GSFC, the AMPS/Labcraft prime contractor and instrument contractors providing launch support as required. Launch operations then proceed with handover to the JSC/MCC Flight Operations Team for post launch, orbit insertion and Spacelab activation. The GSFC POCC payload team now supports the MCC in initiating on-orbit experiment operation and provides continuing ground science support and direction to the in-flight lead, a scientific payload specialist charged with implementing the scientific mission objectives. MCC, through the flight commander, retains overall control of the mission and responsibility for the safety of the crew and the orbital vehicle. The MCC assumes total control for deactivation and reentry recovery; KSC takes over the landed vehicle; science data is returned to the investigators by GSFC; and other centers' data is distributed by GSFC or JSC after non time critical processing is completed.

II PROGRAM MANAGEMENT

The Martin Marietta Corporation's plan for managing the AMPS Phase C/D program is presented in this section. This plan describes the functions, organization and techniques required to manage and control the activities related to the design, development, production and/or acquisition of the flight support and ground support equipment needed to implement the first two AMPS flights.

It presents and discusses program and project schedules and defines the management techniques and the performance measurement systems that will be used by management to monitor, assess and control the program and thereby provide an efficient and economical Phase C/D program for AMPS.

This plan is specifically designed to provide visibility into management processes and thereby assure that the technical and cost targets are attained throughout the program life.

A. Program Definition and Schedules

The AMPS prime contractor effort encompasses hardware/software elements that must be integrated with various NASA and related contractor organizations as well as the scientific community in order to meet key milestones, tests, decision points, interfaces and hardware/software deliveries.

The functional elements of which the AMPS Phase C/D program is comprised are those as delineated in the Work Breakdown Structure (WBS), Table II-1. This WBS is also the basic planning structure and provides the framework for development of program schedules, cost and the performance control system.

The program, project, development and major element activities, keyed to the WBS, is depicted in schedule form in Figure II-1 and in logic network form in Figure II-2. This overall schedule plus those to be developed at the lower level WBS levels will provide the basic time phasing tools required by GSFC, Martin Marietta and other program participants and will also provide the basis for implementation and/or further delineation for the Phase C/D program planning and control functions.

Significant aspects of this program schedule show that the first flight is targeted for July of 1981 and the second for July of 1982. To meet the first targeted flight date, the Announcement of Opportunity for the instruments is released in March of 1977 and instrument definition is started in the last quarter of 1977.

For both the instrument developer and the prime contractor design activity, preliminary design reviews (PDRs) are held when the interfaces are 90% defined, at which time the end item specifications and interface

Table II-1 AMPS Work Breakdown Structure (WBS)

Level 3	Level 4	Level 5
AMPS Prime Contractor	01 Project Management	01 01 Project Administration
		01 02 Project Planning and Control
		01 03 Data Management
		01 04 Procurement Management
		01 05 Configuration Management
		01 06 GFE Management
	02 Systems Engineering & Integration	02 01 Mission Analysis & Rqmts.
		02 02 System Anal., Design & Integ.
		02 03 Specifications & ICDs
		02 04 Instrument Rqmts. & Integration
	03 Flight Support Equipment Design & Development	03 01 Structures & Mechanical
		03 02 Pointing Control
		03 03 Electrical Power
		03 04 Data Handling & Comm.
		03 05 Thermal Control & Cryogenics
		03 06 Deployed Instrument Support
		03 07 Controls & Displays
		03 08 Other
	04 Flight Support Equipment Hardware - Manufacturing	04 01 Structures & Mechanical
		04 02 Pointing Control
		04 03 Electrical Power
		04 04 Data Handling & Comm.
		04 05 Thermal Control & Cryogenics
		04 06 Deployed Instrument Support
		04 07 Controls & Displays
		04 08 Assembly, Integration & Checkout
	05 GSE & STE D&D	05 01 Electrical
		05 02 Mechanical

Table II-1 AMPS Work Breakdown Structure (WBS)

Level 3	Level 4	Level 5
AMPS Prime Contractor	06 GSE & STE Manufacturing	06 01 Electrical 06 02 Mechanical
	07 Software Development	07 01 Software Requirements 07 02 Flight Software 07 03 Ground Software
	08 Product Assurance	08 01 Quality & Reliability 08 02 Safety 08 03 Parts, Materials & Processes
	09 Science Support	
	10 System Test	10 01 System Test Requirements 10 02 System Test Operations
	11 Ground Operations	11 01 Requirements & Planning 11 02 Level I/II/III Integ. Support 11 03 Level IV Integration 11 04 Logistics 11 05 Post-Flight Operations 11 06 Maintenance & Refurbishment
	12 Mission Operations Support	12 01 Mission Planning 12 02 Data Processing 12 03 Mission Control 12 04 Crew Training 12 05 Post-Mission Evaluation
	13 Facilities	13 01 Requirements Analysis 13 02 Budget Estimates

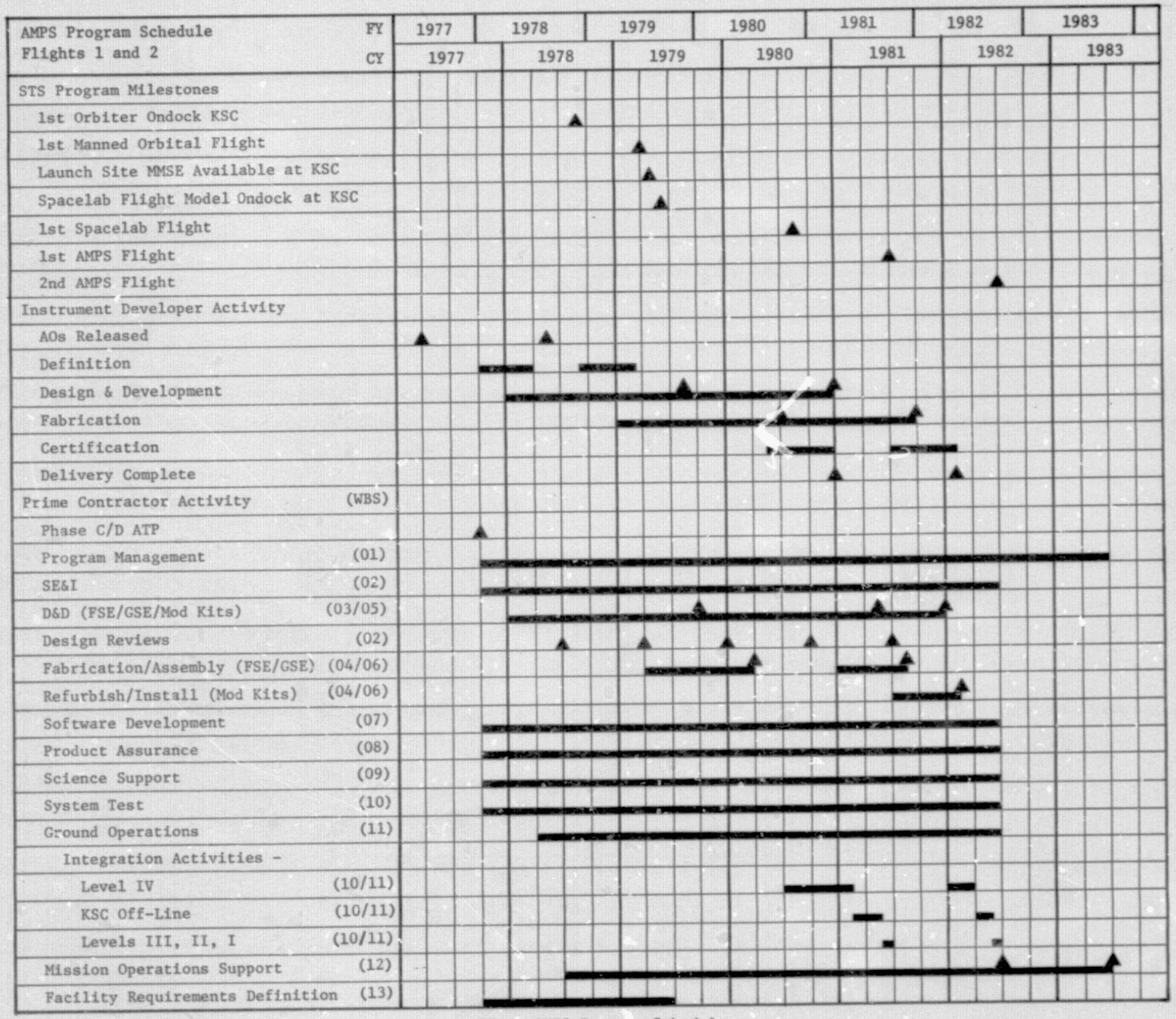
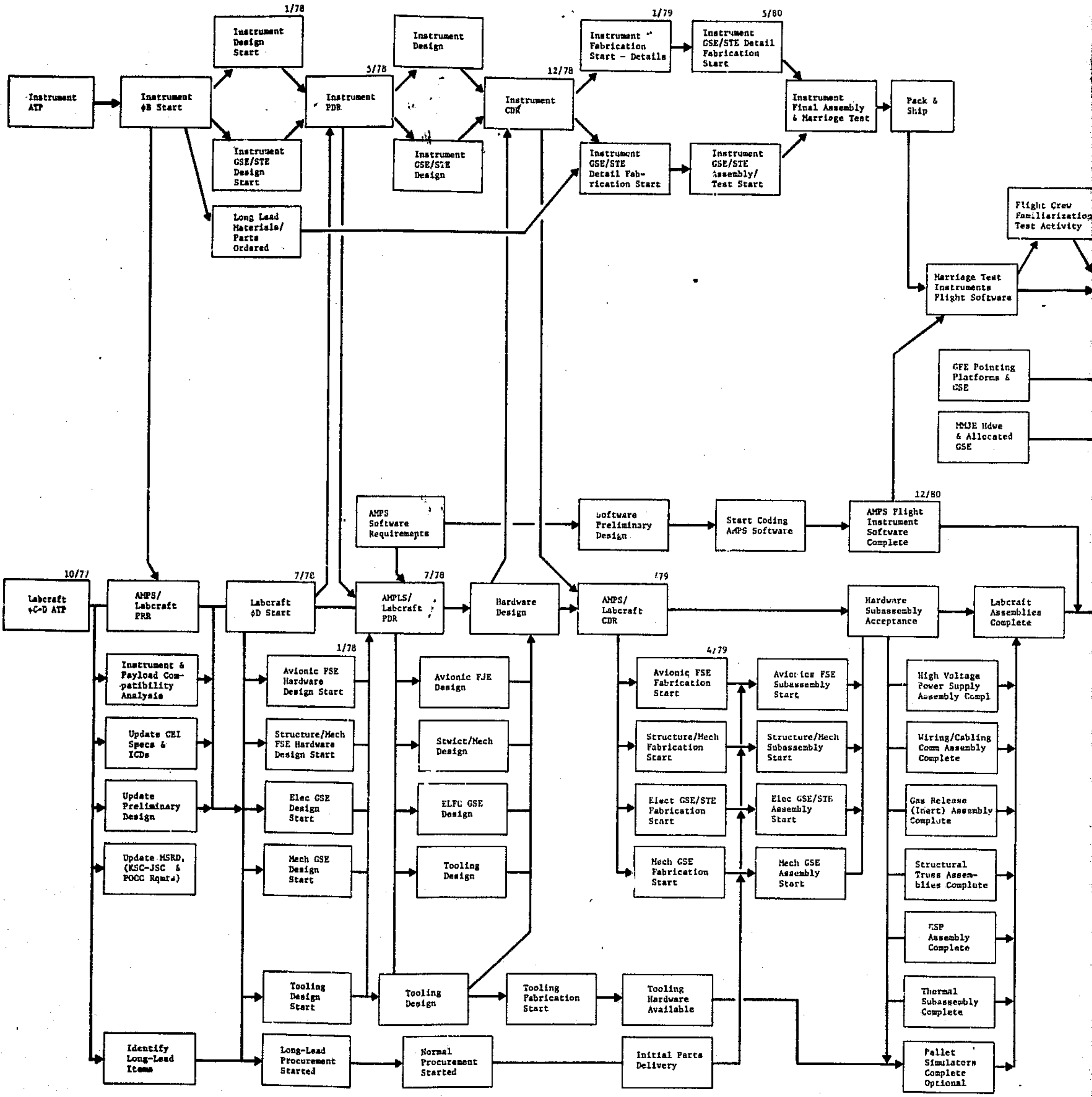
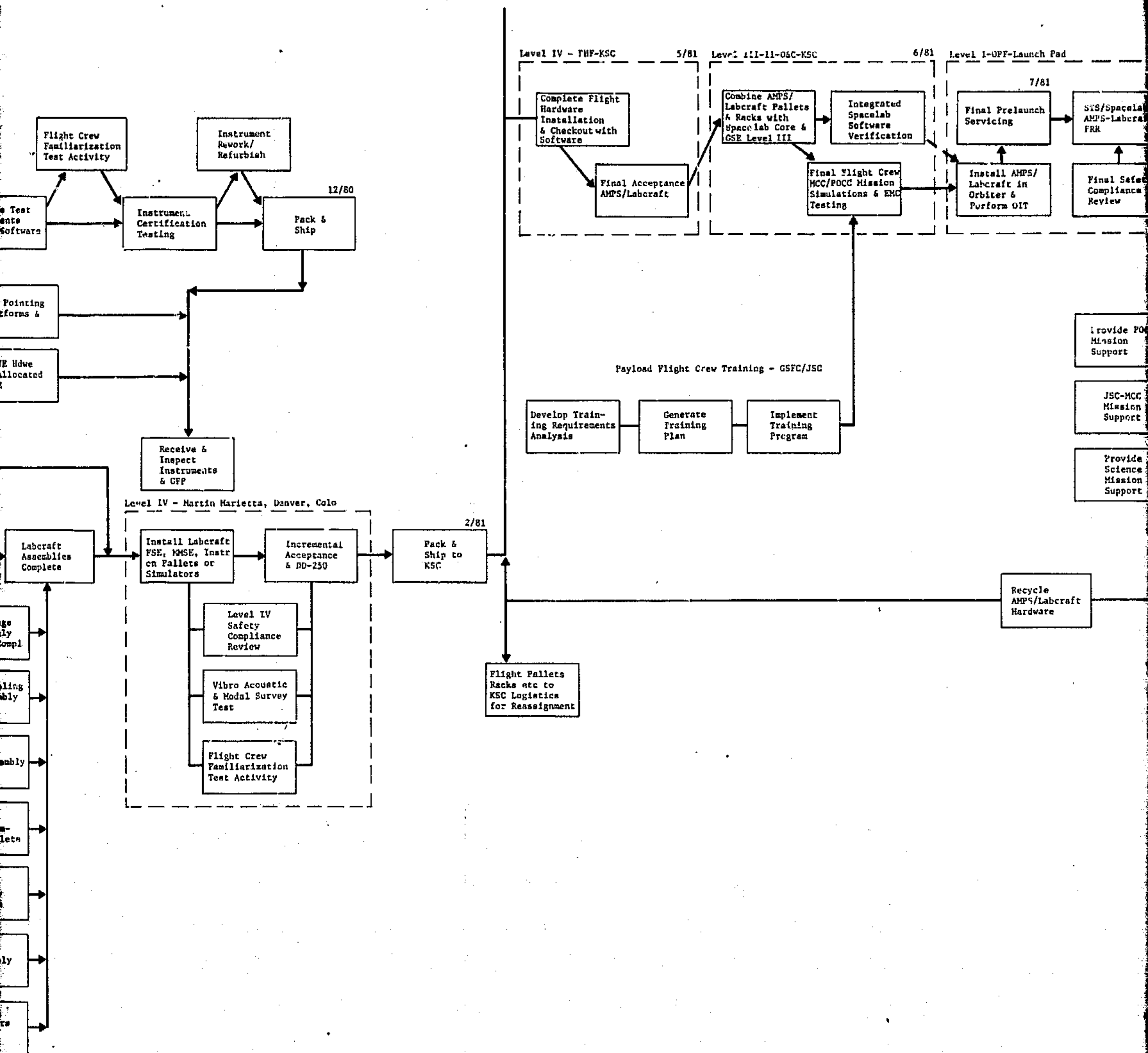


Figure II-1 AMPS Program Schedule



FOLDOUT FRAME 1


Flight Crew Familiarization Test Activity
Instrument Rework/ Refurbish
12/80
e Test ents Software
Instrument Certification Testing
Pack & Ship
Pointing tforms &
E Hdwe llocated
Receive & Inspect Instruments & GFP
Level IV - Martin Marietta, Denver, Colo
Labcraft Assemblies Complete
Install Labcraft FSE, MMSE, Instr on Pallets or Simulators
Incremental Acceptance & DD-250
Level IV Safety Compliance Review
Vibro Acoustic & Modal Survey Test
Flight Crew Familiarization Test Activity
2/81
Pack & Ship to KSC
Flight Pallets Racks etc to KSC Logistics for Reassignment
Recycle AMPS/Labcraft Hardware
Level IV - THF-KSC
5/81
Complete Flight Hardware Installation & Checkout with Software
Final Acceptance AMPS/Labcraft
Level III-II-O&C-KSC
6/81
Combine AMPS/ Labcraft Pallets & Racks with Spacelab Core & GSE Level III
Integrated Spacelab Software Verification
Final Flight Crew MCC/POCC Mission Simulations & EMC Testing
Level I-OPF-Launch Pad
7/81
Final Prelaunch Servicing
STS/Spacela AMPS-Labcra FRR
Install AMPS/ Labcraft in Orbiter & Perform OIT
Final Safet Compliance Review
Payload Flight Crew Training - GSFC/JSC
Develop Training Requirements Analysis
Generate Training Plan
Implement Training Program
Provide PO Mission Support
JSC-MCC Mission Support
Provide Science Mission Support

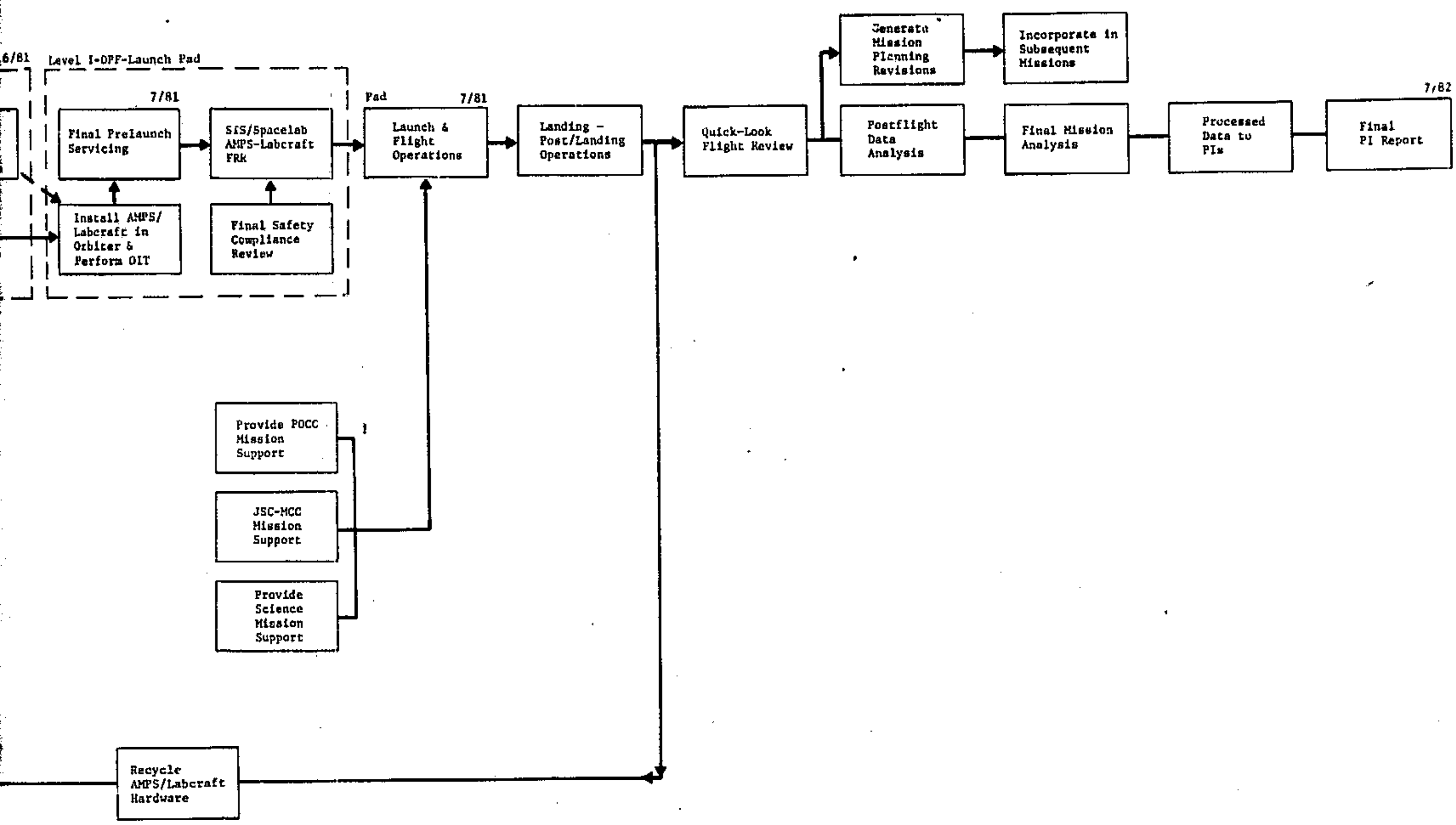


Figure II-2 AMPS/Labcraft Logic Network Flow

FOLDOUT FRAME 3

control documents are baselined and put under control. The PDRs vary somewhat for the individual instruments but generally are completed prior to the Flight Support Equipment (FSE) and Ground Support Equipment (GSE) PDRs so that the instrument interfaces can be defined and accommodated by the support systems.

Critical Design Reviews (CDRs) are held when the engineering is 90% complete and prior to assembly. Again, although the CDRs for the individual instruments may vary, they will generally precede the CDR for the support systems.

The AMPS/Labcraft hardware and software for orbital operations will be developed in conjunction with ground and test support equipment which augments that already under development for the orbiter, spacelab and multi-use mission support equipment. GSFC will draw on separately procured AMPS/Labcraft equipment including the Small Instrument Pointing System (SIPS) and other related GSFC hardware. The prime contractor will conduct Level IV integration, hardware/software initial flight integration, and test. FSE designed and built by the prime contractor will be combined with the SIPS and applicable MMSE on flight pallets, if available, or on prime contractor supplied pallet simulators at the prime contractor facility. Instruments which have been pre-qualified by the new GSFC instrument certification facility will then be integrated into the SIPS (or other pointing mounts), installed in racks, or mounted on the pallet substructures and finally assembled on the pallet simulators, cabled up and plumbed in with the FSE equipment. During final assembly, the complete flight system will be checked out and tested using the GFP central 370 computer augmented as required to verify safe hardware operation with the AMPS/Labcraft developed scientific application software and compatibility with the STS/Spacelab executive software for flight and related ground software to be used later for KSC integration and Level III, II and I testing. The integrated, assembled pallets and experiment racks with all installed flight equipment are packed and shipped to the KSC AMPS/Labcraft payload handling facility for final pre-delivery checkout and installation onto the flight pallets, if required, through completion of Level IV integration. All experiment equipment will have been integrated and checked out prior to GSFC handover to KSC for conduct of Level III, II and I integration activities.

Level III, II and I testing proceeds to completion and the KSC Spacelab team hands over prime responsibility to the STS operations team with GSFC, the AMPS/Labcraft prime contractor and the instrument contractors providing launch support as required. Following the first flight, modifications for flight 2 are incorporated. The schedule for the second flight is similar to that of the first except that the time available for the integration is more limited because of the turnaround time limitations. Modification kits for the support systems are available at KSC on completion of the first flight. The support systems are refurbished and modified and the instruments for the second flight are installed. Integration at all levels is completed in six months in time to meet the July 1982 targeted flight date.

The major non-hardware WBS elements such as Program Management, Systems Engineering and Integration, Software Development, Product Assurance, Science Support and System Test are scheduled basically over the life of the program although the amount of effort over this four-plus year span of prime contractor activity is not constant but varies in accordance with the level of activity in the hardware design and operational activity phases.

B. Program Organization

The management challenge is to provide a set of FSE and GSE that will meet not only the needs of the first two AMPS flights at the projected costs but also the subsequent scientific missions planned by GSFC using the FSE in a Labcraft approach. To meet this challenge, we will structure our AMPS project organization to provide direct management participation. Our organizational approach will feature direct lines of communications to the highest levels of our Corporate and Division management. We will assign the disciplines and commit the resources required for effective management and control. The AMPS Program Director and his team will have the required AMPS, systems and NASA contract experience. The team will be collocated in a dedicated area and will operate under a task oriented concept designed to augment a low-cost development approach.

The Martin Marietta Corporation recognizes the role of the AMPS program as a major element in the NASA Shuttle Payloads plan. The AMPS Program Director will report directly to the Director of NASA Programs who, in turn, reports directly to the Vice-President and General Manager of the Denver Division (Figure II-3). Thus the Vice-President and General Manager is closely involved in the overview of the AMPS program activities and will continually evaluate the technical and programmatic performance as the program advances through its development. Further, he will provide executive level assistance to the Director of NASA Programs and to the AMPS Program Director in obtaining needed support from the Denver Division and other Corporate resources.

Our AMPS program organization (Figure II-4) has been structured to emphasize task management and preclude responsibility/accountability handoff. The program organization will have short lines of communication and clearly defined areas of responsibility.

Our AMPS team will establish program requirements and criteria, identify and authorize the work to be performed, establish budget and schedule requirements, monitor and report to management on program status and performance and maintain coordination with GSFC on program matters. To meet these responsibilities, our team has full authority to draw upon the extensive Denver Division resources for additional support.

1. Program Director -- The AMPS Program Director is responsible for the management and direction of all Martin Marietta activities

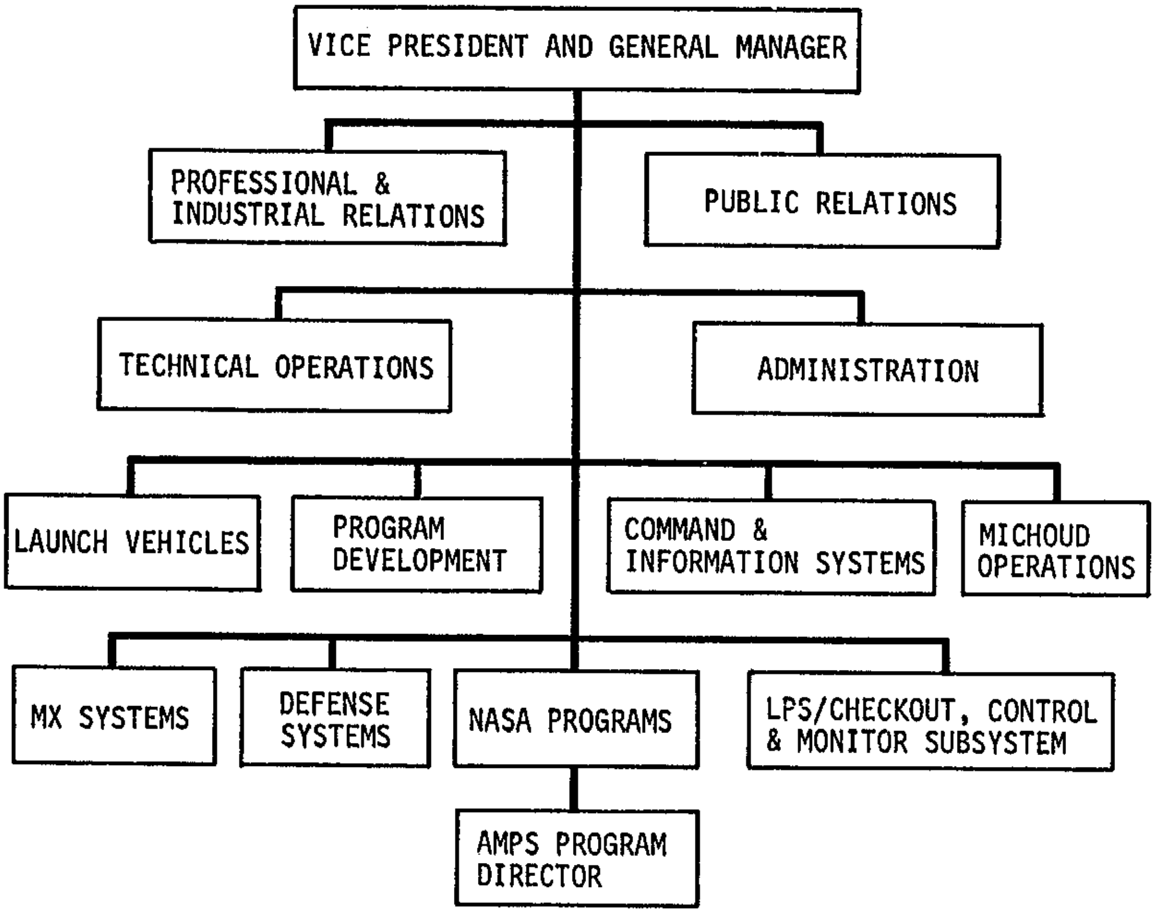


Figure II-3 Denver Division Organization

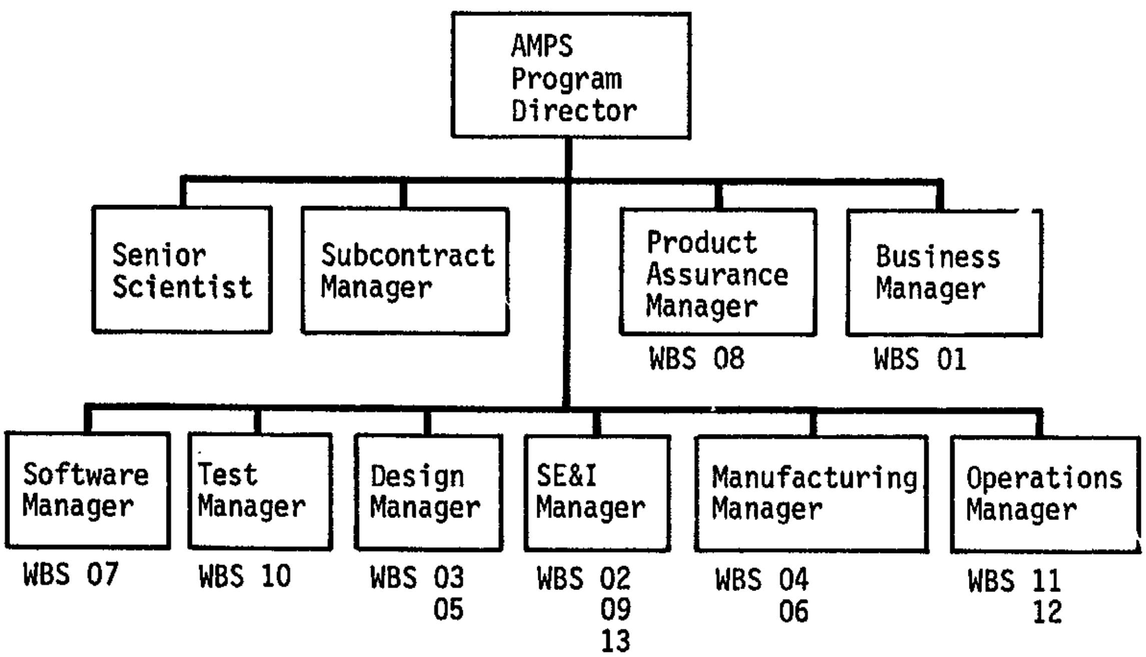


Figure II-4 AMPS Program Organization

related to the AMPS program. He has an unlimited formal delegation of authority to represent and commit the Corporation in matters dealing with the fulfillment of contractual obligations. He will direct program activities, conduct program reviews to assure the technical integrity of our design, manage the program cost elements and maintain overall responsibility for meeting schedule milestones.

2. Subcontractor Manager -- We have selected Bendix as our major subcontractor for our AMPS program. They will provide expertise in the areas of attitude and pointing control, communications, controls and displays and experiment integration. Key Bendix personnel assigned to AMPS are physically located in the AMPS program area at the Martin Marietta Denver Division with all Bendix AMPS activities being under the supervision and review of the Bendix program manager. He will report directly to the Program Director and will be responsible for committing all required Bendix resources, accounting for their performance and, through his AMPS liaison engineer receive support from Teterboro in gaining access to the detailed design and cost information available in their product areas.

3. Product Assurance Manager -- The Product Assurance Manager is responsible for establishing and maintaining effective quality assurance, reliability and safety programs across all elements of the Phase C/D activities. These tasks include reviews to assure the incorporation of quality and safety requirements in the design selection and fabrication of materials, components, subassemblies, final assemblies, acceptance test reviews and final approval and acceptance of all delivered hardware for the Martin Marietta Corporation. He is also responsible for the program activities related to calibration and failure analysis, production support and the identification, tracking and status of engineering and hardware discrepancies, and the development of program product assurance procedures and controls.

4. Senior Scientist -- The Senior Scientist, supported by our in-house team of discipline specialists, performs the multiple role of advising the Task Managers as to the scientific objectives of the AMPS program, monitoring to see that all functional activities are in consonance with those objectives and providing required support to the scientific community and the instrument developers.

5. Business Management -- The business management staff consists of those activities related to contract management.

a. Contract Administration -- Responsible for negotiation and administration of the AMPS contract and all changes thereto; preparation and control of the work authorization operation directives; operation of the change management program; configuration accounting; control of documentation; and primary accountability of GFE.

b. Planning and Cost Management -- Responsible for development and implementation of program-level schedules, approving all supporting-level schedules, and monitoring and evaluation of program

schedule performance. Responsible for implementation of the performance measurement system; issuance, updating and monitoring of program budgets; maintaining financial accounting systems; and providing financial status, analysis and reports for Martin Marietta and NASA management.

c. Materiel Management -- Responsible for the acquisition of required materials, components and assemblies within the cost and schedule constraints of the program. Under the direction of the cognizant task manager, the Materiel Manager processes, controls and provides status on all procured or acquired items including GFE and spares; the buying operations; and inventory management including the receiving of all procured and subcontract material items, GFE, spares, and warehousing of received components and commodities.

6. Task Managers -- The Task Managers for design and software are charged with the total responsibility of design, development, qualification and fabrication of the AMPS FSE and GSE hardware and software. These Task Managers have total budget authority and are held responsible for the technical performance of their AMPS items. Each Task Manager will be provided with a statement of work, within the framework of the contract, represented by the WBS element(s) for which he is responsible. The Task Manager will also receive cost targets and technical performance goals against which he will be evaluated.

a. FSE and GSE Design Manager -- This Manager has overall responsibility for the detail design and development of the AMPS Flight Support and Ground Support Equipment. This will include the AMPS/Spacelab subsystem design, structures, dynamics, APCS, thermal, electrical, I&C, data management, crew systems, subsatellite systems and the GSE required for checkout and verification. He will direct and control all engineering disciplines.

b. Software Manager -- The Software Manager will be responsible for the development of flight software requirements to sufficient detail to permit fully developing the AMPS system software. He will also be charged with developing ground test software for use in checkout and verification testing of the AMPS hardware in conjunction with the GSE.

c. System Test Manager -- The System Test Manager is responsible for developing integrated test requirements for the AMPS system, planning and conducting development testing to support design and planning, and conducting systems test verification at Martin Marietta. Our plan calls for conduct of Level IV integration tests at the Martin Marietta facility, off-line testing at KSC and then support to the Level III, II and I integration activities at KSC. The System Test Manager will be responsible for planning, conducting and supporting these activities.

d. Systems Engineering and Integration Manager -- This Manager has responsibility for engineering and integration activities to ensure the AMPS design meets all performance and design requirements and that design is compatible with all STS and Spacelab requirements and constraints. He is also responsible for definition and control of requirements, weight management, compatibility analyses, reviews, specifications and interface control documents.

e. Manufacturing Manager -- This Manager has responsibility for procuring and/or fabricating and assembling all FSE and GSE hardware required in support of the program. He will also be responsible for performing the quality control inspection and the required acceptance and/or production testing of the hardware.

f. Operations Support Manager -- This Manager has responsibility to define requirements and provide plans and procedures for ground operations and mission operations support. His team will perform Level IV integration; provide logistic support including transportation, spares and training; maintain and refurbish the support systems; support mission operations and process data; support crew training; and evaluate mission performance.

This task-oriented manager concept, with the functional and service organizations reporting directly to the Task Managers, provides management visibility, personal accountability and motivation.

C. Performance Management

The performance management system will measure and control planned versus actual cost/schedule/technical performance. This system will integrate work authorization, scheduling, budgeting, cost accumulation, performance measurement, management reporting and analysis, and customer reporting through the WBS and the organization structure.

1. WBS Accountability -- Responsibility for major WBS elements have been assigned to individual Task Managers as shown in Figure II-4. This assignment includes work scope, schedule performance, budget and cost control, variance analysis and corrective action. The basis for implementing this effort is task work packages and level-of-effort work packages for every WBS element.

2. Program Work Authorization -- All work to be performed on the program will be initiated through Operations Directives (ODs). Each OD will be reviewed and approved by the Program Director. These ODs will define the authorized work, identify the manager or managers responsible for implementation, describe technical requirements, establish cost targets, authorize distributed budgets and direct schedule requirements.

3. Planning and Scheduling -- Proven planning techniques will be applied to integrate program elements to produce a master schedule and

WBS element schedules. From the WBS element schedules, the Task Managers will direct that detailed working schedules be developed for each functional department, i.e., engineering, manufacturing, etc. Our plan is to maximize use of previously qualified and residual hardware from other programs that meet our requirements.

There will be program control milestones for each WBS work package. Schedule statusing and milestone tracking will be correlated with WBS schedules to show progress by each WBS element. The cost aspects of the system will be integrated with schedule and technical requirements so that the impact of any changes will be visible on the total performance baseline.

4. Budgeting -- The contract cost agreement established during contract negotiations will become the budget baseline. The Program Director will extract a management reserve that will be held as a separately identified class of funds. The status of this reserve, controlled at the appropriate contract level, will be visible to GSFC. Planning and Cost Management is responsible to administer the management reserve and to maintain records that provide traceability to the use of such funds. Formal allocations of funds from these accounts will be made only at the direction of the Program Director.

The balance of the contract cost remaining after the establishment of the management reserve is the program's performance measurement baseline. This baseline is subdivided and allocated to designated control-level WBS elements as cost accounts, and to the functional organizations responsible for performing the work defined in the contract statement of work, under the direction and control of the WBS Task Manager. Planning and Cost Management establishes and applies controls to assure that the sum of the allocated budgets (including authorized changes plus management reserve) equals the original contract budget baseline plus the authorized changes.

5. Cost Management -- The WBS Task Managers have the responsibility for accomplishing task efforts, within the established cost target, for assigned WBS elements. The steps that will be used to manage cost performance to cost targets are shown in Figure II-5.

Actual manpower will be tracked on a weekly basis. This manpower report showing plan, actual and variance will be provided to the Program Director and his managers on a weekly basis. An analysis of all WBS costs will be made against the budget values on a monthly basis. Included will be labor dollars, material commitments, other direct charges and overhead. Variances will be identified and brought to the attention of the Program Director and his Managers.

6. Performance Measurement and Analysis -- Performance measurement and analysis of schedule and cost data will be the responsibility of the Business Management group in direct support of the Program Director and his Managers.

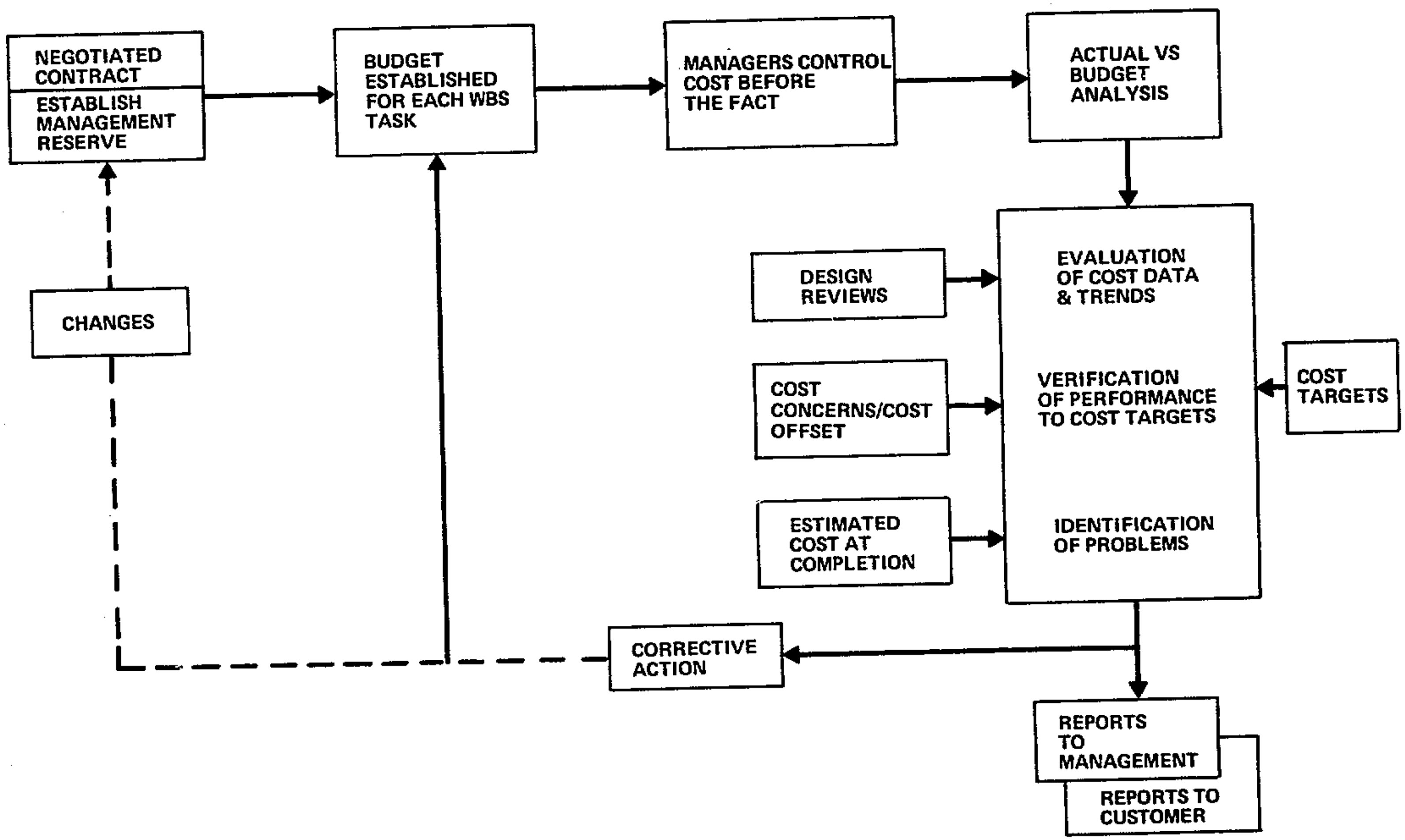


Figure II-5 Control to Cost Targets Approach

Performance measurement will be made at designated levels of the WBS, where schedules, time-phased resource plans and actual costs are integrated.

Schedule performance will be measured each week by comparing actual or promised completion dates to planned schedule dates. A determination will be made of the scheduled work accomplished.

Cost performance will be measured each week by comparing actual manpower costs to the planned value of work scheduled (budget plan). An example of the format to be used is provided in Figure II-6. This example is recommended because it represents a return to basics. For any cost/schedule performance criterion, the question that must be answered is, "If the money is X% spent, is the job X% complete?".

The format in Figure II-6 is for WBS element 04 07, Assembly, Integration and Checkout for Controls and Displays. A deviation to the planned spending curve becomes apparent as both a function of time and as a function of milestone completion. Any replan of the curve will be documented in a change block, as will any change in milestone dates. At all times this element of program cost will be under surveillance, the estimated final cost of the element will be known, schedule changes will be apparent, and any adjustments from beginning to completion will be presented in a change block.

Our performance management is keyed to the WBS Task Managers. They are assigned the responsibility and necessary resources, and are held accountable for performance.

The Program Director will hold weekly and monthly status meetings with his Managers and staff to review cost/schedule/technical performance. The monthly review will be in greater depth and detail than the weekly status reviews. GSFC is invited to attend these meetings.

The Program Director will use a cost-concern/cost-offset system. This is a discipline to identify potential cost problems and cost savings, so that total program impact can be assessed and evaluated. A cost concern is initiated if a potential cost overrun is identified. The system is outlined in Figure II-7. The Program Director will hold a weekly meeting with his Managers and management staff to review new cost-concern/cost-offsets that have been submitted and to assess action items on those already in work.

D. Configuration and Data Management

Configuration management will provide the control of technical requirements which define the products to be delivered. The following functions will be performed as detailed in subsequent paragraphs:

1) Configuration Identification and Accounting
2) Baseline Management and Design Reviews
3) Configuration Control
4) Documentation Management

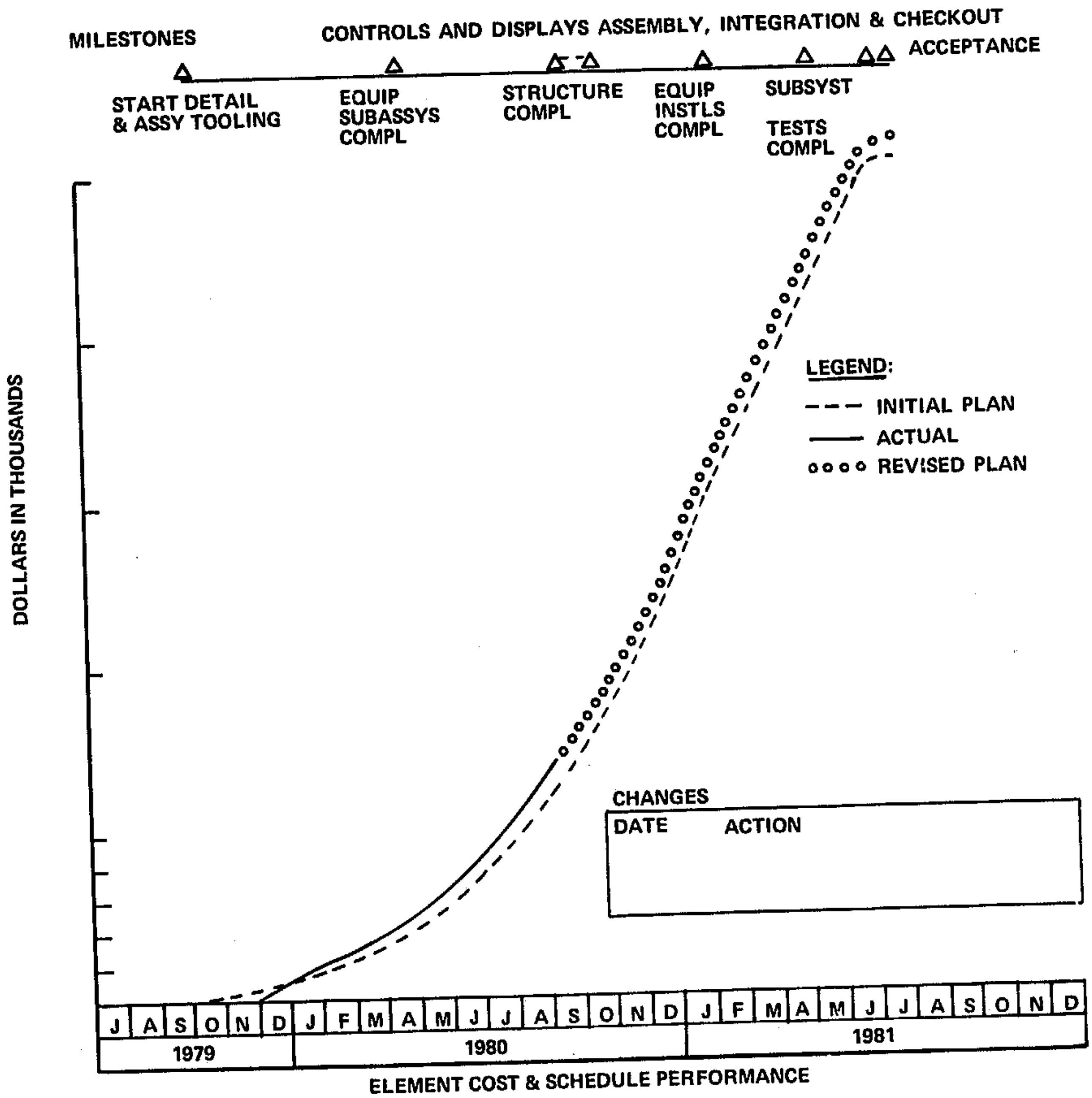


Figure II-6 Sample Cost Performance Report Format

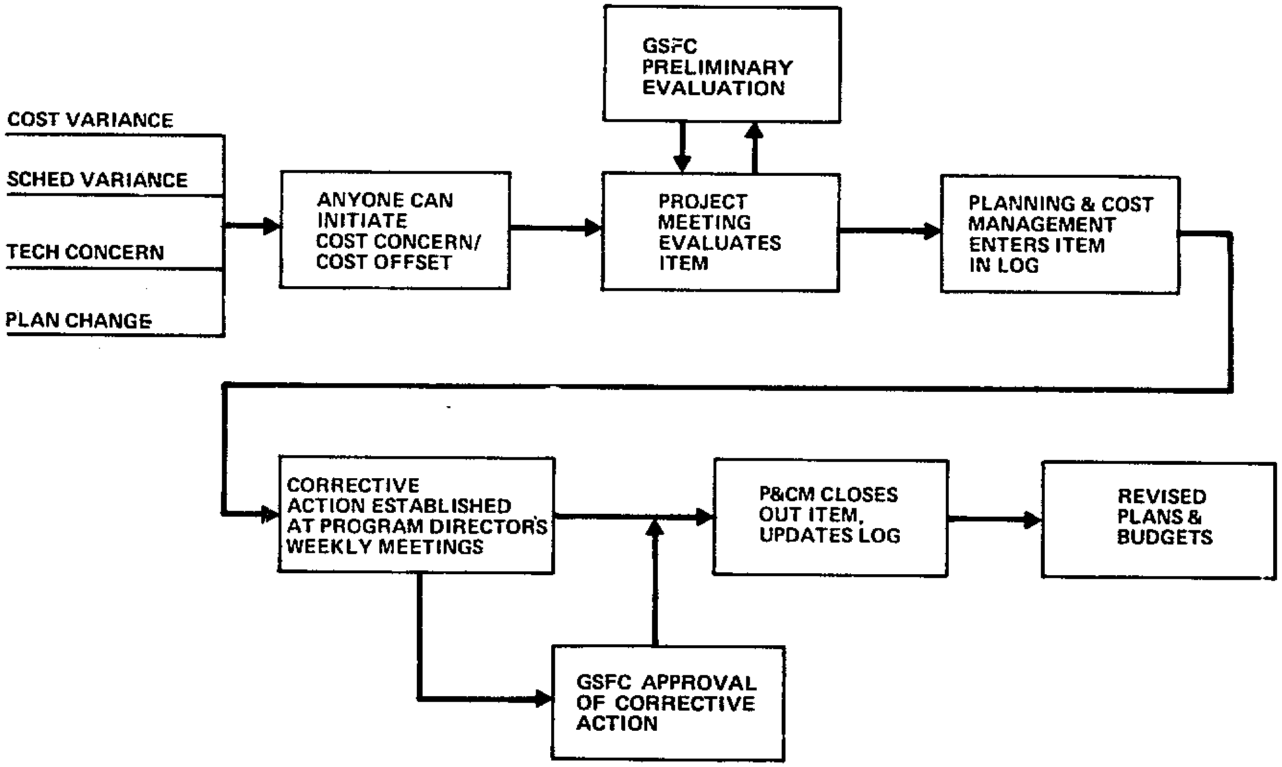


Figure II-7 Cost Concern/Cost Offset Approach

The Configuration Management relationship to the program and the Configuration Management functions are shown in Figure II-8.

1. Configuration Identification and Accounting -- Configuration identification for the AMPS program will be established at the CEI level in the form of technical documentation. Initially, the CEI specification will define the performance and design requirements for the design and development of the AMPS equipment. Engineering drawings will then be developed which establish the design and build requirements. The engineering drawings will incorporate interface requirements defined in the Interface Control Documents (ICDs) which will reflect agreements between interfacing elements.

An on-program engineering release system will be established that will develop and maintain a record and change status of all released engineering. The release system will provide a single point of release and a formal procedure for assigning and controlling document numbers, verifying release requirements, effectivity and approval signatures, and recording and transmitting documentation required to support fabrication and test.

AMPS configuration accounting to maintain, store and correlate configuration documentation status will be developed to define the as-designed, as-built, as-qualified, as-flown and as-refurbished configuration accounting data.

2. Baseline Management and Design Reviews -- Approval of technical and program documentation resulting from scheduled reviews will serve to establish hardware and software baselines. The design reviews will be conducted to assure that the evolving design implements the technical requirements.

The AMPS design reviews will consist primarily of the Preliminary Design Review (PDR) which will establish the design requirements baseline; and the Critical Design Review (CDR) which will establish the released design baseline.

3. Configuration Control -- Configuration control will be established to assure a systematic evaluation, coordination and disposition of proposed changes to established baselines and requirements. AMPS configuration control will be accomplished through a contractor Configuration Control Board (CCB). The CCB will assess the total impact of all changes and submit Class I changes to GSFC for approval. The change flow for contractor changes is shown in Figure II-9.

4. Data Management -- Data management will provide the identification and control of documentation required for the AMPS program. It will establish documentation preparation responsibilities; monitor and control the development of documentation to meet program schedules; and inspect and transmit documentation to GSFC.

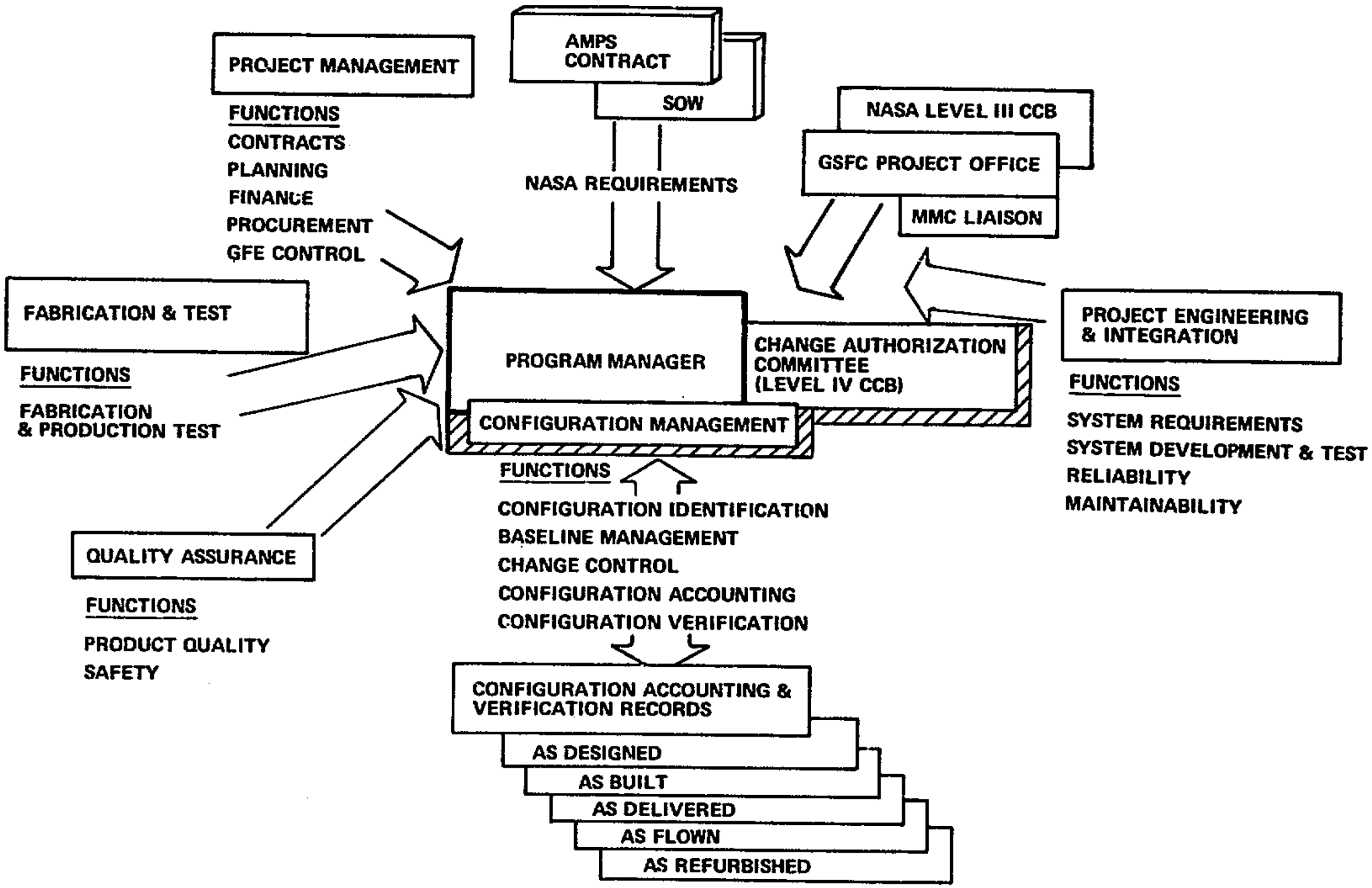


Figure II-8 Configuration Management Functions and Program Relationships

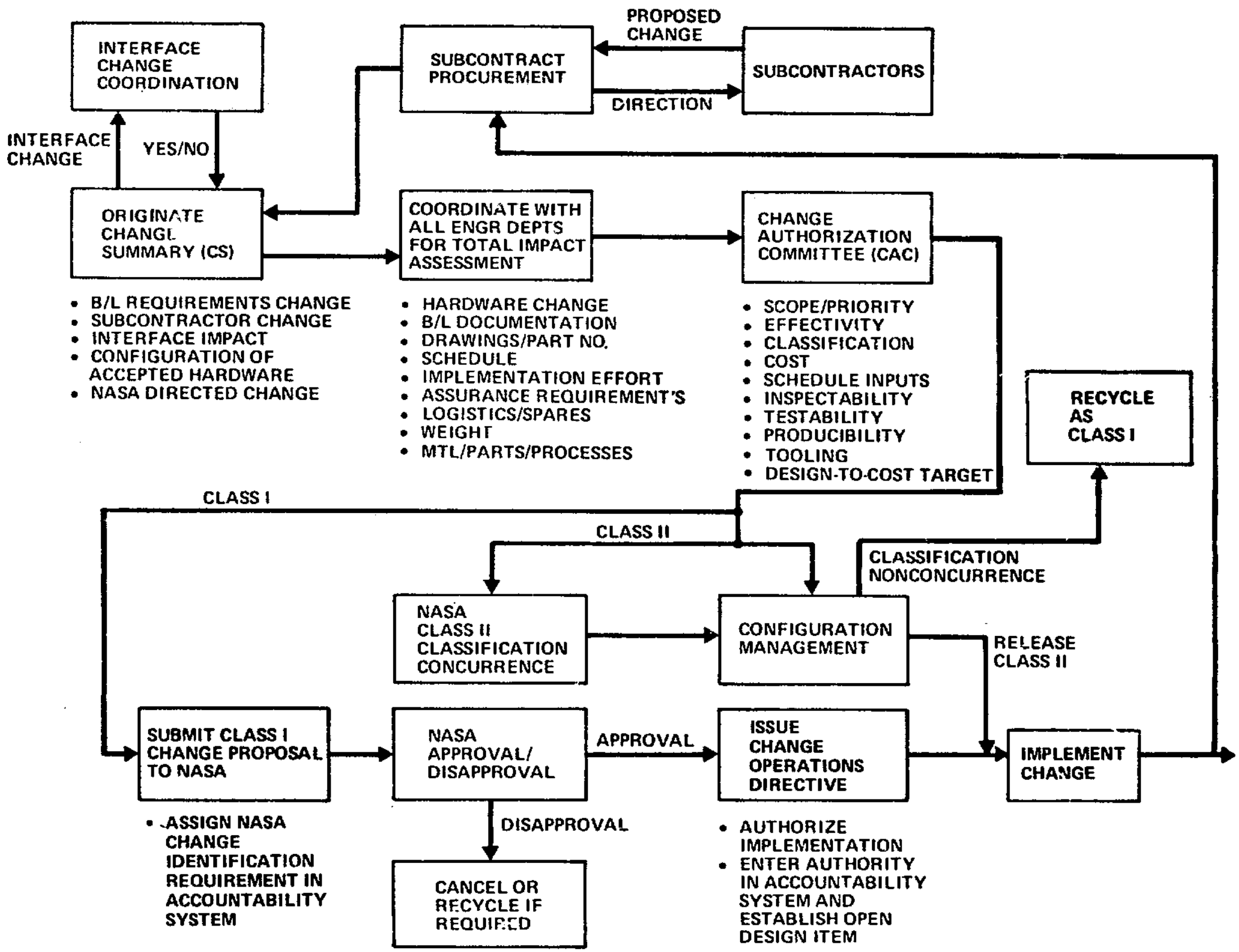


Figure II-9 Configuration Control Change Flow

The categories of documentation required are identified in a Data Requirements List (DRL). The DRL generated from our Phase B study, defining the general categories of documents to be delivered is given in Table II-2. This is a sample DRL and will be baselined during Phase C/D.

E. Procurement and Subcontract Management

Our existing approved Procurement Management System includes the necessary controls to assure performance and provides flexibility to meet AMPS program requirements. The effectiveness of our system has been demonstrated in the successful placement and management of over $500 million of subcontracts during the last 10 years. Major elements of our system are discussed in the following paragraphs as they apply to AMPS program requirements.

Experience has shown that effective procurement action requires the formulation of a sound procurement plan. Pursuant to any decision to subcontract/procure, we prepare, coordinate and issue a procurement plan which includes all key milestone events leading to subcontract/procurement definitization. The procurement plan is structured within the framework of the total program master plan and issued with the approval of the Program Director. After release, the plan will be maintained in a current status by periodic updating. Such updating will include narrative reports providing necessary detail to indicate current status, problem areas, actions proposed or being taken and a summary of any changes to the previous plan.

Within 30 days after the date of selection, an orientation conference between Martin Marietta and the subcontractor will be held. The overall objective of this review is to reaffirm that each subcontractor understands the technical, schedule and cost requirements, has established an acceptable plan and is proceeding with implementation.

Monthly management reviews of the subcontractor effort will be conducted wherein the technical, schedule, cost and overall performance will be assessed. The Task Managers will be responsible for directing actions and assigning responsibilities resulting from these reviews.

We will conduct formal, scheduled mission assurance audits to verify that each subcontractor is complying with the reliability and quality requirements of the program. Formal configuration management audits will be conducted to assure compliance with configuration and change control procedures. Task Managers will attend the formal design reviews. Corrective actions identified in these formal audits and meetings will be directed by the Task Manager. Follow-up audits will be held to assure compliance.

Engineering, subcontract management, planning and finance functions will ascertain progress by visits, telephone, telefax and TWXs as required in day-to-day interchanges with the subcontractor.

Table II-2 Sample Data Requirements List

Management
- Management Plan
- Project Schedules
- Monthly Progress Reports
- Monthly Financial Mgmt Report
- Subcontract Management Plan
- GFP Maintenance Plan
- New Technology Plan

Data Management
- Information Management Plan
- Information Accessioning List

Configuration Management
- Configuration Management Plan
- Configuration Vfcn Accounting Reports
- Specification
- Spec Change Notice & Revision
- Engineering Change Proposals
- Change Status & Accounting
- Interface Control Documents
- Deviations & Waivers

Engineering
- Design Drawings & Lists
- Mass Property Status Reports
- AMPS Program Systems Description/ Handbook
- Manuals, Training & O&M
- Design Review Data Package
- Software Development Plans
- Software Functional Rqmts
- Software Test Plans
- Software Program Description Doc.
- Software User's Document
- GSE/STE Requirements Document
- EMC Control Plan
- Contamination Control Plan
- Experiment User's Guide

Test Management
- Master Verification Plan
- Integration & Test Plans
- Test Reports
- Manufacturing Plan
- Subsystem Development/Qual Plans

Produce Assurance
- Quality, Reliability & Safety Rqmts
- Failure Mode & Effects Analysis
- Critical Items List
- Parts, Materials & Processes Plan
- End Item Acceptance Data Package
- Nonconformance Reports
- Hazard Analysis Report
- Accident/Incident/Mishap Report

Mission Support Operations
- Mission Ops Rqmt Document
- Support Instrumentation Rqmts Doc
- Mission Rqmts & Control Document
- Mission Data Acquisition Rqmts & Distribution Plan
- MCC Functional Requirements
- Operations Data Handbook
- Mission Evaluation Reports
- Design Reference Mission Documents
- Mission Preparation Documents
- Flight & Launch Mission Rules & Constraints Document
- Mission Ops Training Plan
- Operation Support Plans

Crew Operations
- Crew Training Plans
- Crew Ops Pland & Procedures
- Inflight Maintenance Rqmts Doc.

Launch Operations
- Test Checkout Rqmts & Spec Doc.
- Payload Handling Processing Plan
- Payload Launch-Safety Assessment
- Test & Checkout Procedures

Ground Operations
- Logistics Support Plans
- Maintenance Support Plans
- Ground Operations Refurbishment Requirements Document
- Refurbishment Plans
- Refurbishment Procedures
- Handling & Transportation Plan

III SYSTEMS ENGINEERING AND INTEGRATION

The AMPS Systems Engineering and Integration (SE&I) task defines payload, integration and program requirements; performs analyses, trades and studies to define optimum performance and design requirements; performs interface and design verification analysis; maintains configuration control; and prepares the payload specifications, ICDs, etc.

The work content of each of the above major activities, along with our plan to implement and carry out the effort is defined in detail in the following sections:

A) Mission Analysis and Requirements
B) Systems Analysis, Design and Integration
C) Specifications and ICDs
D) Instrument Requirements and Integration

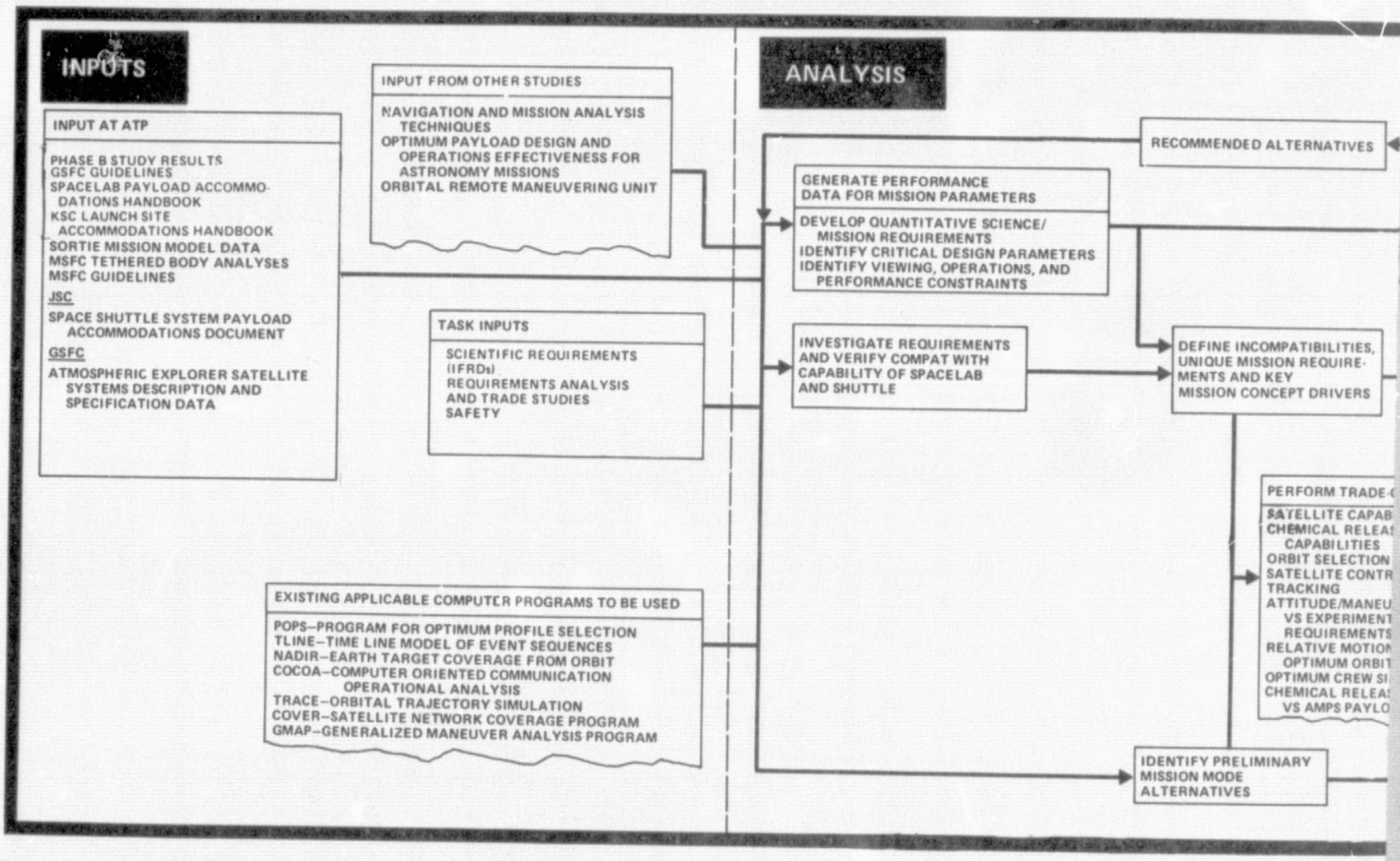
A. Mission Analysis and Requirements

This task will develop mission requirements and perform mission compatibility analysis and planning to support the design of the AMPS payload. The analysis activities will include mission sensitivity analysis to define critical mission design requirements and will include mission sequence requirements analysis to develop the mandatory sequence of STS/AMPS payload hardware functions for incorporation into the integrated mission timeline.

The approach to performing this task, including the inputs and outputs, is shown in Figure III-1. Utilizing the results from the Phase B study and other pertinent data such as existing computer programs, updated instrument and experiment data and results from other studies, we will generate mission operations criteria, requirements and constraints, and mission phase impact on all elements of the AMPS payload.

The task will also analyze ground and flight mission operational requirements and constraints and provide design criteria; define mission operational modes; analyze relationships between subsystem capabilities and science requirements; establish mission operational sequences; define mission operations procedures and criteria; allocate functions between ground and on-board; define mission operations requirements on software and hardware.

Concurrently we will perform mission compatibility analysis to verify compatibility of AMPS to the capability of the STS and to define any unique and key mission requirements. Trade studies will be conducted to determine the best and most cost effective solutions to incompatibilities and key mission requirements drivers. Examples of key drivers include: understanding of attitude control requirements based on instrument pointing, antenna- and boom-imposed constraints and experiment operation requirements; and definition of real-time



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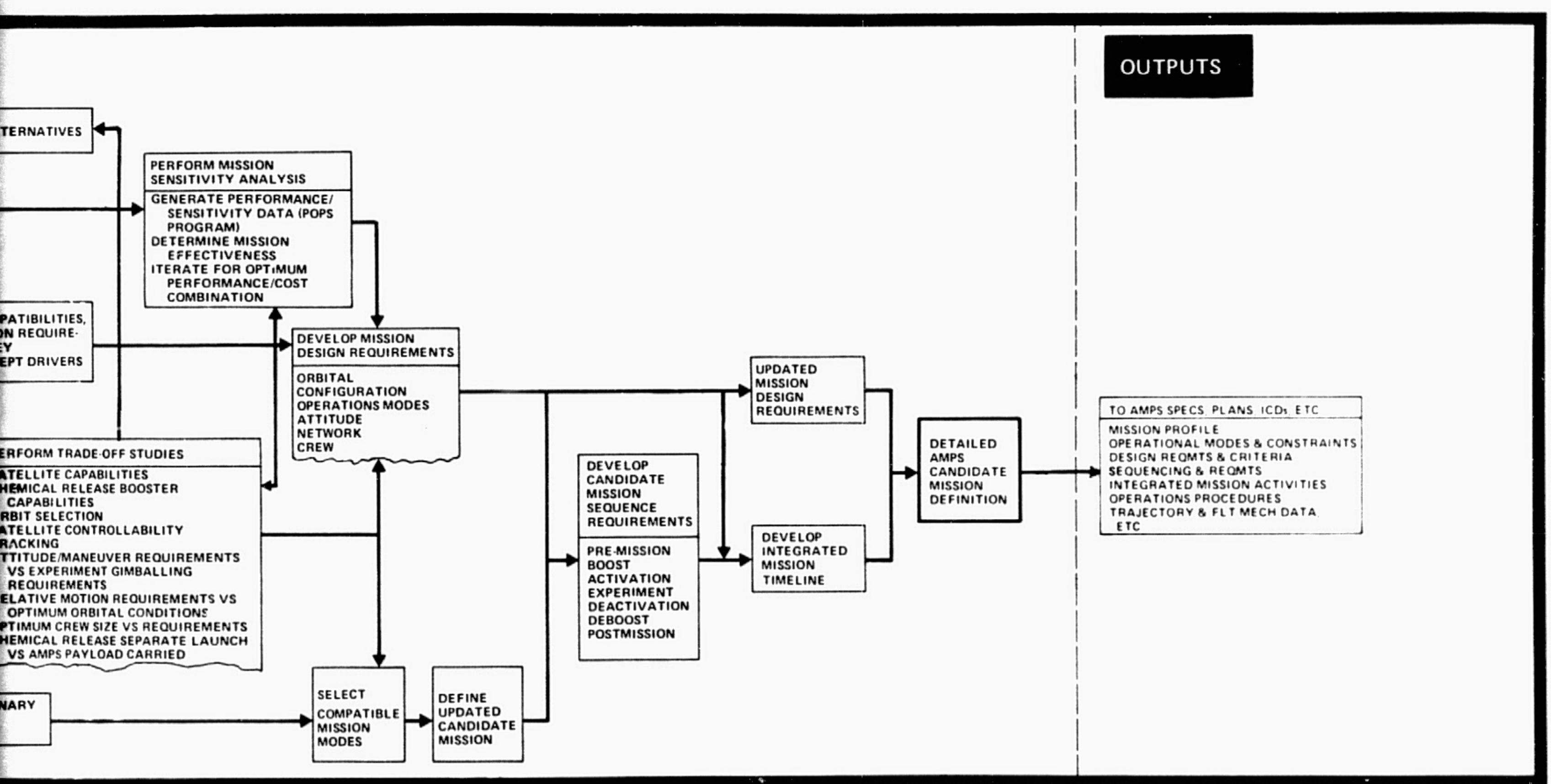

Figure III-1 Mission Analysis and Requirements Approach

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experiment activity concepts that provide evolving development and flexible mission performance.

The mission sensitivity analyses will define the critical mission design requirements necessary to satisfy the scientific requirements. The analysis will vary system and mission design parameters to determine the resulting science performance impacts on the mission with emphasis on optimization of mission design with minimum cost.

The primary output is an integrated mission timeline incorporating instrument/experiment requirements with crew activities, network coverage, orbital mechanics, etc. and a payload mission profile compatible with the STS.

The task will also perform mission operations review activities and provide surveillance over, and control of, subsystem design to assure compatibility with mission operations requirements.

B. Systems Analysis, Design and Integration

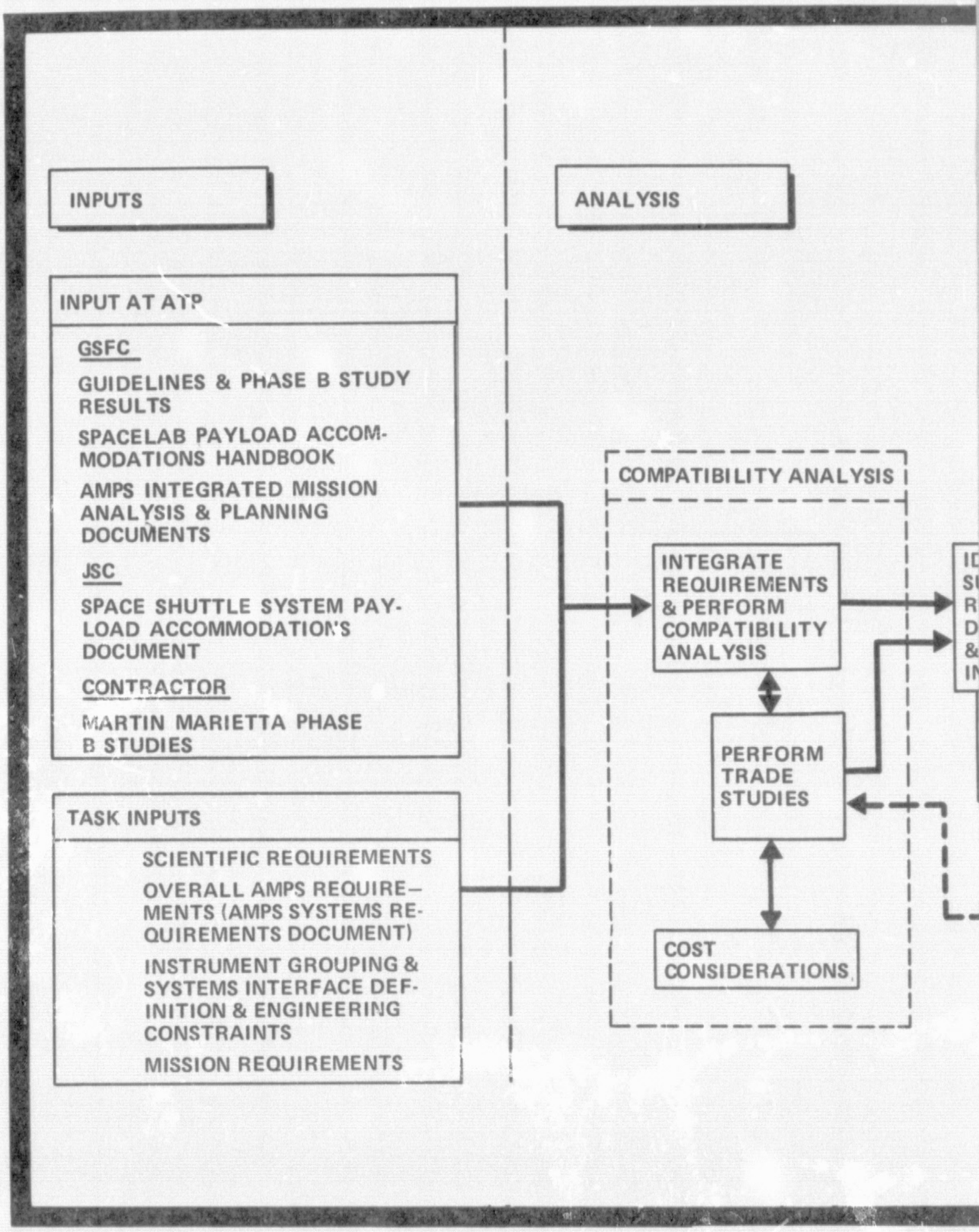
This task includes the definition of flight and ground support equipment requirements and performs requirements compatibility, interface analysis and trade studies to define the performance and design requirements for the payload; verify design solutions and approaches; and assure compatibility of AMPS to the Spacelab and Shuttle. The detail and approach to performing this task are covered in the following paragraphs:

1) Requirements Definition,
2) Requirements Analysis and Trade Studies,
3) Compatibility Analysis,
4) Interface Analysis,
5) Spacecraft Environments,
6) Contamination Analysis,
7) Mass Properties Analysis,
8) Crew Systems Analysis,
9) Configuration Control, and
10) Design Reviews.

1. Requirements Definition -- Beginning with the results of the Requirements Definition effort of the Phase B study, the system and subsystem requirements (FSE, GSE, Facilities & Instruments) will be updated and maintained to support the design and development of the AMPS payload.

a. Instruments Requirements -- The plan to update and maintain the science, instrument and experiment requirements is covered in detail in Section III-D, "Instrument Requirements and Integration".

b. Flight Support Equipment (FSE) Requirements -- The approach that will be used to update and define additional FSE requirements is shown in Figure III-2. FSE is defined as all flight hardware required



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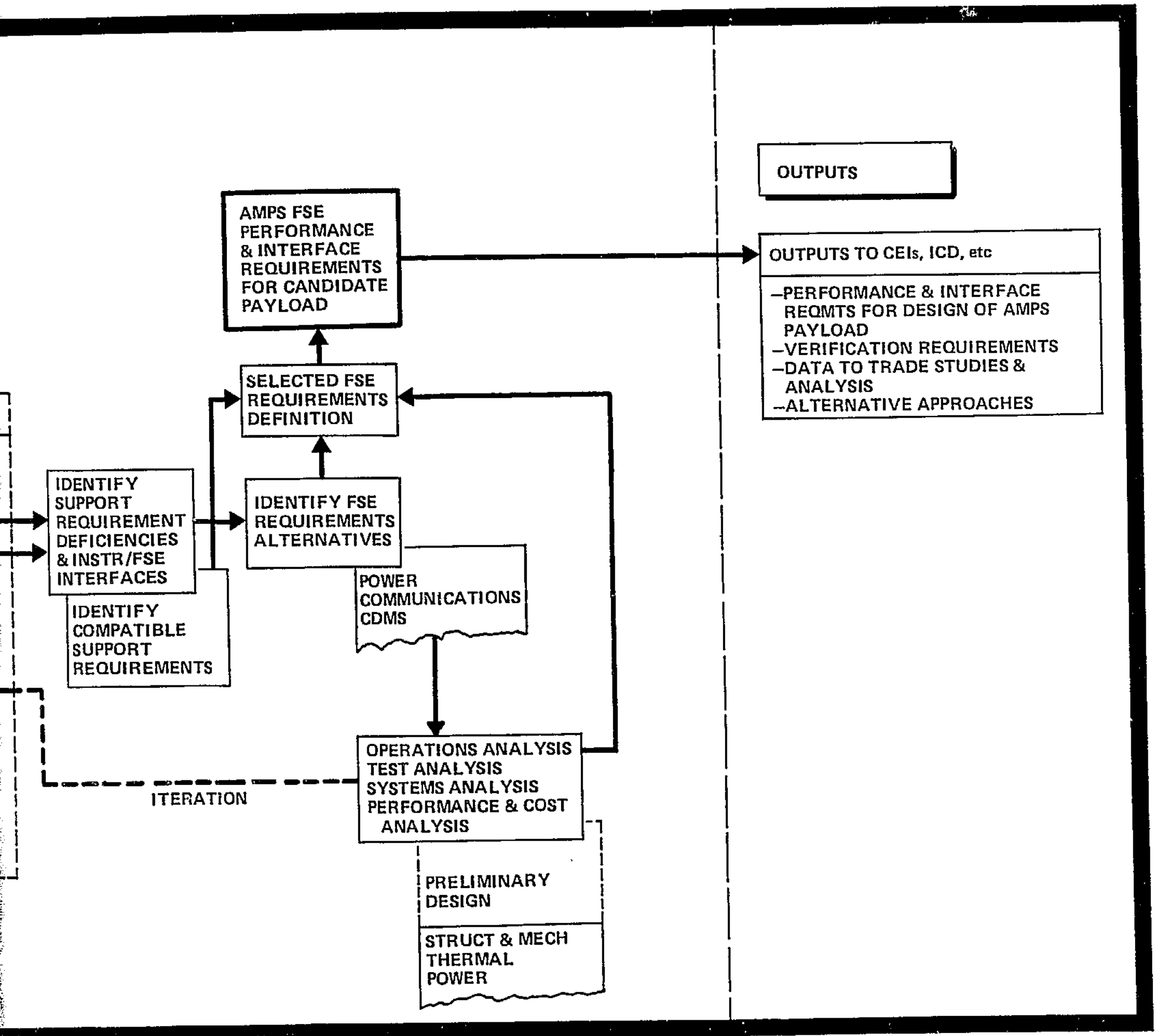

Figure III-2 FSE Requirements Approach

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to support the scientific instruments and supplements that support equipment provided by the Space Transportation System (STS).

Starting with the updated instrument requirements and the latest Shuttle/Spacelab accommodations data, a Compatibility Analysis (Ref: Section III-B-3) comparing requirement with carrier capability will be performed. As necessary, trade studies will be conducted to make maximum use of the Spacelab capabilities and to minimize incompatibilities that may result in AMPS unique flight support equipment. Where incompatibilities are found to exist, FSE requirement alternatives (i.e., hardware/software, requirement change, etc.) will be identified to eliminate the deficiency. From a performance standpoint, we will consider manual operation versus automated operations, portability, etc. Through update of the design goals and other related tasks we will define the FSE performance and interface requirements for the payload before conduct of the Preliminary Requirements Review (PRR).

FSE requirements will be continuously updated and maintained as baseline changes occur and will be documented in the AMPS specifications and interface control documents.

c. Ground Support Equipment (GSE) and Facility Requirements — The GSE and facility requirements definition task consists of determining the requirements for ground support facilities and equipment for manufacture, test and checkout, training, transportation, handling, installation, calibration and storage of the AMPS payload elements.

From the task inputs shown in Figure III-3, a systems analysis will be performed to determine the test and checkout, calibration, interface, stimuli, data, software, line replacement unit (LRU), etc. requirements. Also an in-depth analysis of the ground processing functional flow will be performed to identify those requirements that impact the GSE or ground facility requirements. Timelines that sequence the functional requirements and establish need dates for hardware will be determined from the AMPS master schedule and as further defined by the Phase B study results. The GSE systems analysis will be an iterative process and updated as necessary to reflect baseline changes.

To assure an effective utilization of available GSE and facilities, the Phase B study survey will be continued to determine the availability and applicability of the GSE and facilities from the Shuttle and Spacelab programs, as well as the support equipment that will be available at the NASA Centers and from other programs. Special emphasis will be placed on surveying the Shuttle MMSE for potential use. In the survey of older support equipment, the analysis will pay particular attention to the condition and age of the equipment, as well as the availability of supporting spares. In the interest of reliability and low cost, we will also examine what modifications may be required and the history of recurring maintenance costs. The new, unique GSE requirements will be kept to a minimum.

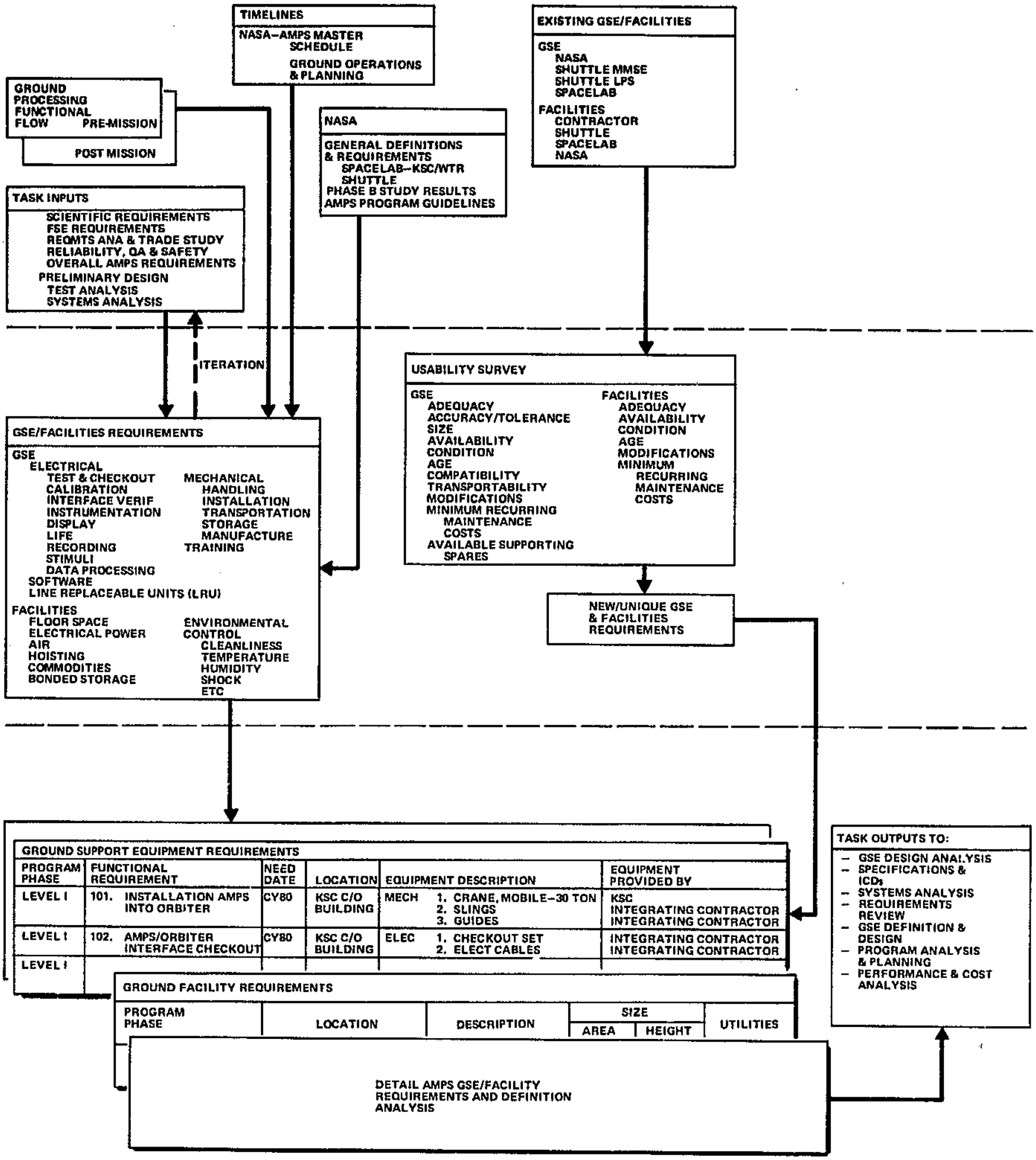


Figure III-3 GSE/Facilities Requirements Approach

The same philosophy used for the GSE review will be applied to the review of the available ground facilities. Because of the major cost impact of any new/unique facility, special emphasis will be placed on the use of existing facilities.

This analysis will culminate in a detailed GSE requirements and definition analysis document as depicted in our study flow outputs. This documentation will be in tabular form and will be expanded as required to meet the program needs. The analysis will cover the requirements for all program phases.

2. Requirements Analysis and Trade Studies -- The objective of this task is to assure the identification of comprehensive and cohesive system requirements for the AMPS program elements. This includes refining and expanding systems requirements, translating analysis results into performance allocations, identifying additional studies, and coordinating requirements concurrence. The AMPS Phase B study has disciplined our approaches and oriented them to the specifics of the AMPS/STS payload.

Figure III-4 illustrates how the plan to perform this task, using our basic analysis and trade study process as the composite activity to analyze requirements and to identify additional studies, will be accomplished.

A key activity of this task is systems level trade studies. Several examples are shown. Interface simplification and reduction will be a basic program requirement.

The requirements synthesis approach, as shown, is an iterative, analytical process that assures a compatible alignment of systems requirements and detailed requirements. Previous and recent experience with Shuttle/Spacelab payload studies has given us an understanding of the capabilities and constraints from hardware through operations. Early in Phase C we will be developing performance requirements based on AMPS programmatic requirements and guidelines, Shuttle/Spacelab accommodations, established operations plans and specific design requirements (safety, contamination, etc.) levied on payloads by the Shuttle/Spacelab programs. As the iterations proceed, AMPS analyses will be translated into firm, well defined requirements for design and implementation.

3. Compatibility Analysis -- Compatibility analysis (CA) will be conducted to assure the compatibility of the instrument and experiment requirements with the capability of the carrier and program. The CA process is shown in Figure III-5. Initially, a CA will be performed to evaluate the impacts of each instrument's requirements upon all other hardware and operational aspects of the program. Then a continuing compatibility surveillance will be maintained to assure that the instrument and experiments requirements and constraints remain compatible with the carrier and program. Some of the disciplines to be evaluated and an explanation of each is provided in the following paragraphs.

SYSTEMS LEVEL TRADE STUDIES

STUDY AREA	OBJECTIVE
CANDIDATE GROWTH APPROACHES TO FSE/GSE DESIGN	EARLY DETERMINATION OF OBTAINABILITY AND CONSTRAINTS FOR CONCEPT TO DEVELOP CRITERIA FOR OPTIMIZATION OF AMPS DESIGN
USE OF STS SYSTEMS CAPABILITY	DETERMINE IF A MEANINGFUL SCIENCE THRESHOLD CAN BE OBTAINED (FOR SOME MISSIONS) USING ONLY SHUTTLE/SPACELAB/MMSE CAPABILITY
CHEMICAL RELEASE BY SEPARATE LAUNCH VS ORBITER PAYLOAD	ESTABLISH MOST EFFECTIVE CONCEPT AS EARLY AS POSSIBLE, CONSIDERING OVERALL INTEGRATION ASPECTS/IMPACTS
RELIABILITY/RISK MANAGEMENT	DEVELOP REALISTIC APPROACH, CONSIDERING AMPS MISSION MODES, FOR DEVELOPING DESIGN CRITERIA
SATELLITE APPLICATION TO AMPS REQUIREMENTS	SELECT EVOLUTION OPTIONS FOR REQUIREMENTS ADDRESSED BY VARIOUS SATELLITE CONFIGURATIONS VARYING FROM EXISTING SYSTEMS TO NEW DEVELOPMENT
DATA PROCESSING—GROUND AND AIRBORNE	ESTABLISH REQUIREMENTS FOR EFFECTIVE CREW INTERACTION AND DETERMINE OPTION FOR PROCESSING AND ALLOCATION BETWEEN GROUND AND AIRBORNE SYSTEMS
MODULARITY FOR INTERFACE REDUCTION/SIMPLIFICATION	DEVELOP CONCEPTS THAT ALLOW P/L CONFIGURATION VARIATIONS OVER MULTIPLE MISSIONS WITH MINIMUM INTERFACE CHANGE
ALLOCATION OF FUNCTIONS FOR HARDWARE VS SOFTWARE (FSE/GSE)	DEVELOP COST SENSITIVITY DATA BASE FOR CANDIDATE P/Ls THAT ASSURE OTPIMUM APPROACH
AMPS PACKAGING APPROACH FOR THE FIRST SPACELAB FLIGHT	OPTIMIZE INTERFACES CONSIDERING AMPS CRITERIA AND OVERALL PROGRAM IMPACTS
INTEGRATED GROUND OPERATIONS	DEVELOP CIS APPROACH CONSISTENT WITH INTERRELATIONS OF TEST, GSE, FACILITIES AND INTEGRATION

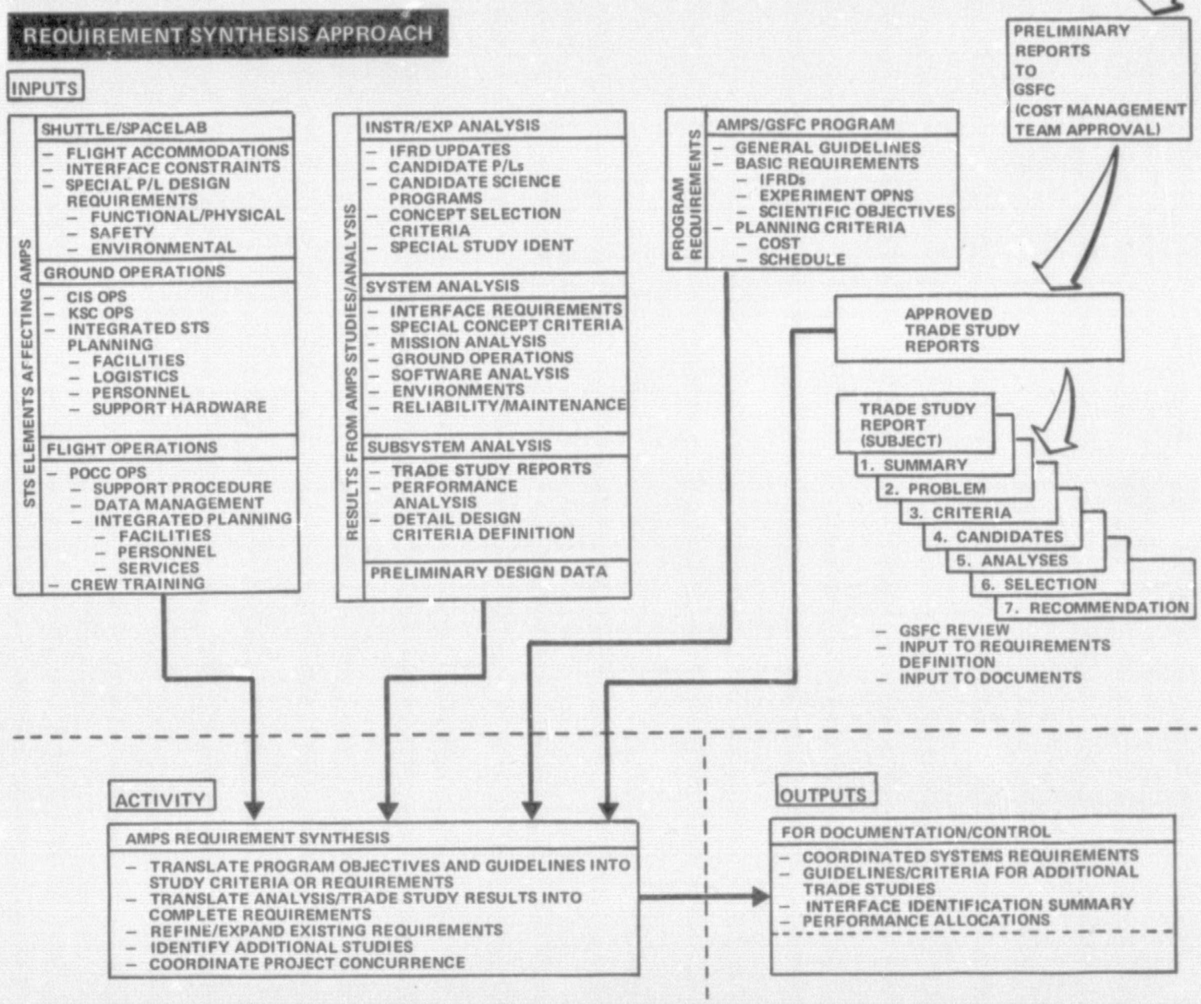


Figure III-4 Requirements Analysis and Trade Study Approach

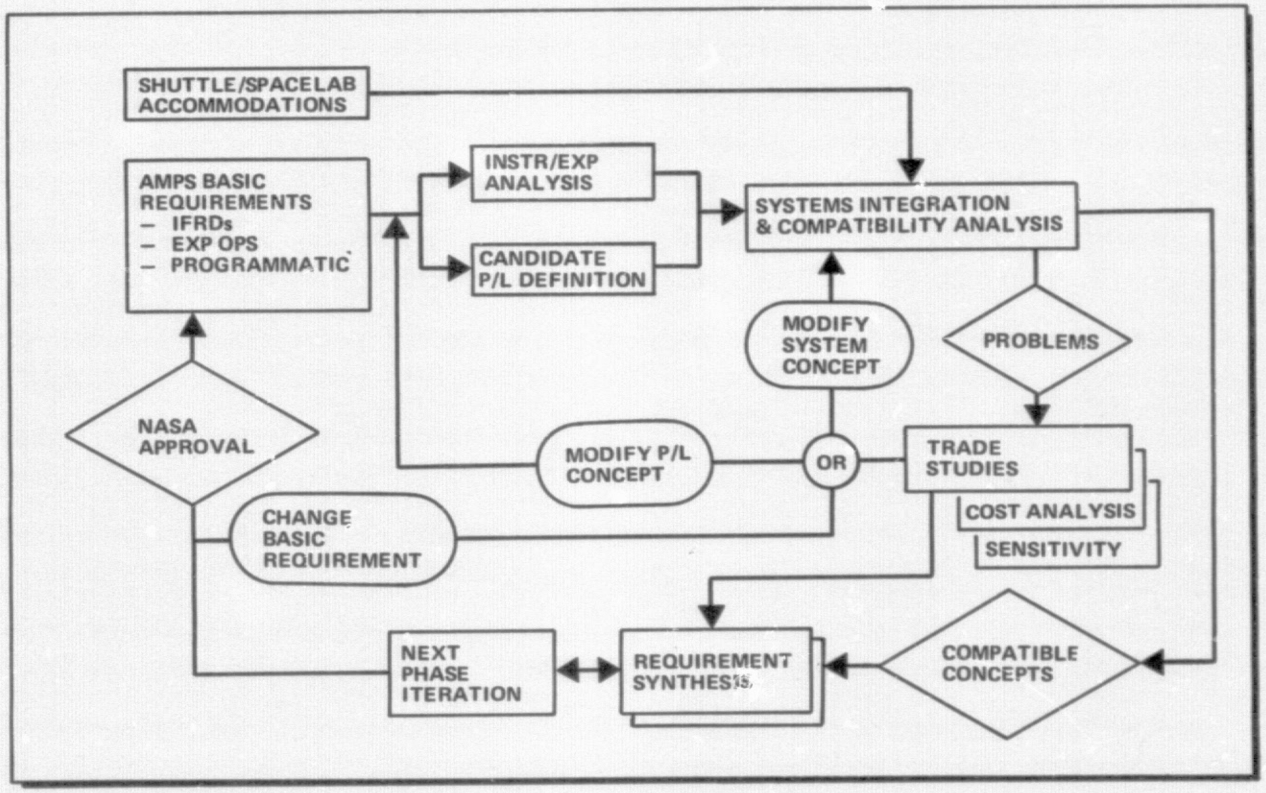


Figure III-5 Compatibility Analysis Procedure

a. Mechanical -- Verification that instrument/experiment mechanical interface requirements are met for mounting, alignment, orientation, plumbing, venting, sealing, and the use of observation windows.

b. Weight and Storage -- Verification of current instrument/experiment weights relative to experiment and module control weights; of experiment stowage provisions in terms of weight, volume and location for each launch, orbital storage and return operation in the mission; and that all on-board support equipment is available at the time and in the quantities required.

c. Consumables -- Verification that instrument/experiment requirements for oxygen, nitrogen, water and/or other consumables will be supplied either by the modules or by the experiments themselves.

d. Electrical -- Verification that instruments/experiments are compatible with the electrical power provided by the module (voltage tolerances, power profile and total energy); that all electrical interfaces are compatible (connectors, cables, etc.); and that EMI produced in the electrical system will not cause unacceptable degradation of the system or experiments.

e. Instrumentation and Communications -- Verification that instrument/experiment measurements, housekeeping measurements, voice communications and ground commands required for the experiments will be provided; that experiment equipment, data formats and data rates will be compatible with module requirements for recording and transmission to ground, and with Martin Marietta requirements for processing and display; that all data correlation requirements (time, ephemeris, etc.) will be provided for; and that experiment-required data will not be lost due to EMI.

f. Environments --Verification of instrument/experiment compatibility with prelaunch, launch, orbital and recovery environments (temperature, humidity, pressure, acoustic, vibration, acceleration, shock, radiation and illumination) as specified or defined by NASA-recognized analyses; and of crew and system compatibility with experiment-induced environments.

g. Materials -- Verification that instrument materials are acceptable in accordance with the appropriate specifications or that waivers to these specifications have been approved.

h. Contamination -- Evaluation of instrument/experiment susceptibility to contamination from internal or external sources; determination of contamination produced by the instruments; and verification of ground contamination control procedures.

h. Photography -- Verification that experiment photographic

requirements (if applicable) are met, including photographic support equipment (cameras, lenses, light, cables, etc.) and film; and that adequate environmental protection is provided for the film.

i. Experiment and Spacecraft Pointing -- Verification that instrument/experiment pointing requirements will be met when integrated into the spacecraft, including orbit position for performance, orientation, stability, allowable rates and accelerations, and the necessary maneuvers, will be provided for.

j. Safety -- Verification of instrument/experiment safety plans and provisions for on-orbit operations.

k. Systems Test -- Verification of compatibility of all instrument handling, test and checkout plans with integration test planning, prelaunch maintenance, logistics, pad access and launch constraints.

l. GSE, Facilities and Handling -- Verification that GSE and facilities provided will satisfy the instrument/experiment post-acceptance handling and testing requirements with minimum duplication.

m. Flight Plans -- Verification of flight plan compatibility with instrument/experiment requirements, priorities, objectives, constraints and interfaces.

n. Crew Interfaces -- Verification of instrument-to-crew interfaces, including in-flight access, restraints and aids, controls and displays, in-flight maintenance and crew training.

o. Mission Support -- Verification of plans for obtaining required evaluation data; for processing, display, analysis and reporting of this data in support of the mission; and for analysis and reporting after the mission.

p. Schedules and Hardware Status -- Verification and comparison of required dates and delivery dates for experiment mock-ups, trainers, flight hardware (including the back-up unit) and GSE.

Management visibility of the instrument compatibility status will be provided by a monthly Instrument/Experiment compatibility status report.

4. Interface Analysis -- Interface analyses will be conducted at all identified program interfaces as shown in Figure III-6. The objective will be to simplify the AMPS interfaces at all levels considering cost and flexibility criteria, but also recognizing the constraints levied by other STS program elements. The analysis approach, as shown in the center of Figure III-6, is supported by the latest STS Accommo-

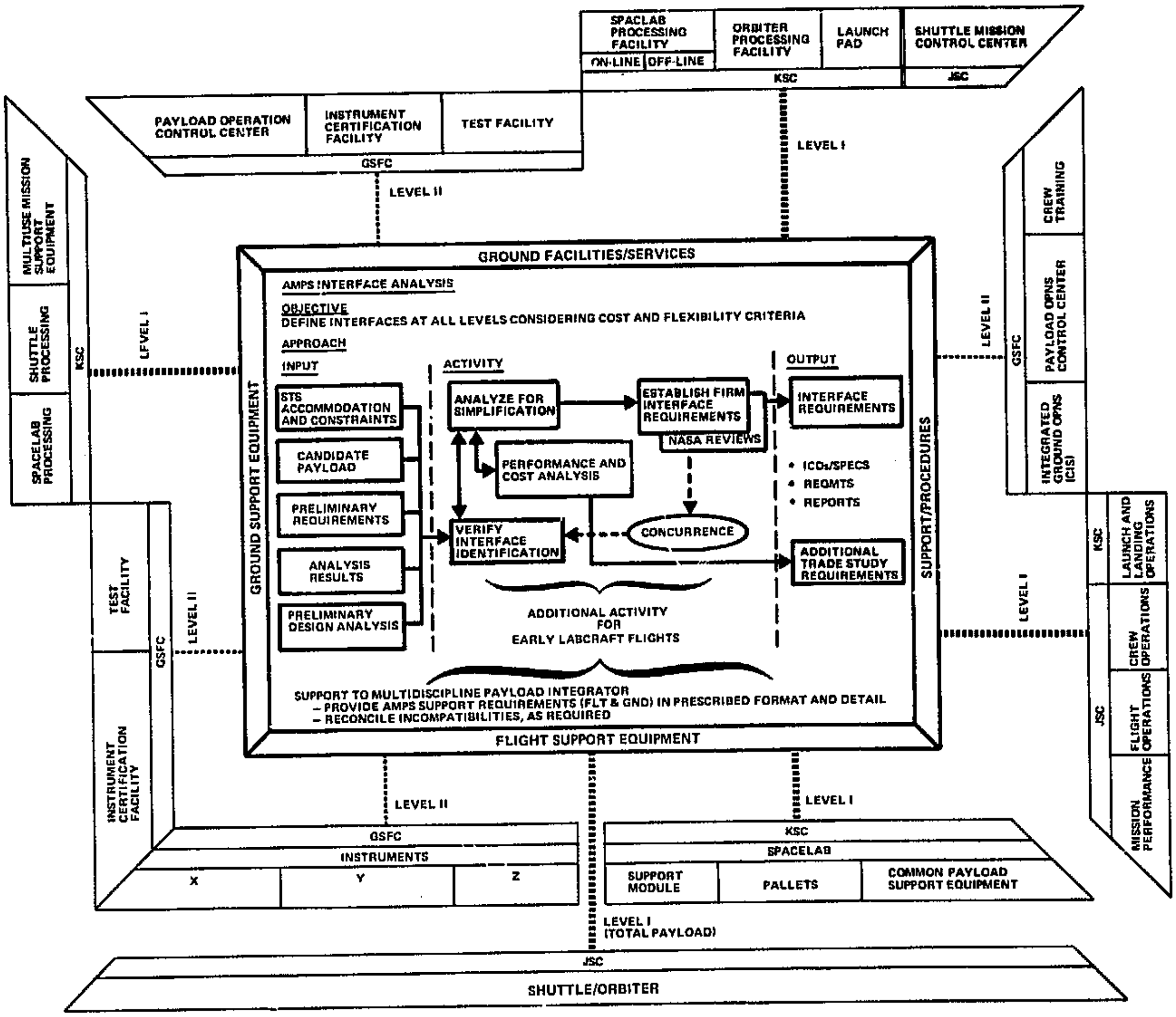


Figure III-6 Interface Analysis

dations data and the Phase B study output data (i.e., candidate payloads, requirements, preliminary design, etc.). This approach will be used to evaluate all interfaces and explore alternatives before in-depth requirements are baselined.

The interface analyses will continue throughout the program -- that is, from conceptual stages through operations. Initially, we will revalidate the STS interfaces affecting hardware definition, design and integration and all other user and center interfaces shown in Figure III-6. Functional relationships such as schematic and flow diagrams will be used to identify interfaces and trade studies and analyses will be conducted to define interface requirements.

The goal throughout the Interface Analysis task will be to simplify all interfaces, particularly those interfaces external to the AMPS program that could have a major impact to program cost and schedule. The approach to the AMPS internal interfaces will be identical. However, more options will be explored since the interfaces are controlled at the same level and broader latitude exists to realize savings in cost and simplified interfaces. The results of the Interface Analysis task will be reflected in the hardware and software end items and in the program interface agreements with other users and centers.

5. Environmental Analysis -- This analysis task will establish the environmental design requirements for the AMPS payload design. Initially we will update the STS environmental design requirements from the Spacelab and Space Shuttle payload accommodations handbooks and the Phase B defined environmental levels for all phases of the mission which includes manufacturing and assembly through postlanding operations.

Concurrently, we will update the AMPS payload components such as instruments and FSE for environmental sensitivities, control requirements and design constraints. Typical environments to be updated for the payload are acoustic, vibration, shock, magnetic, EMI, pressure, temperature, etc. Special emphasis will be placed in the concern areas defined during the Phase B study such as EMI/EMC, spacecraft charging, and effects due to large chemical releases.

Our overall approach is to define the environmental design requirements early in Phase C to detect any major problems early and thereby reduce cost.

6. Contamination Analysis -- The contamination analysis will develop the basis for long-term contamination control for the AMPS program. The approach, as shown in Figure III-7, will be to provide an updated definition of the Shuttle/Spacelab/AMPS-induced contaminant environment; continue the systems analysis of the critical AMPS equipment and contaminant interaction characteristics; and complete the development of the contamination control plan for the AMPS program, encompassing both ground and flight operations.

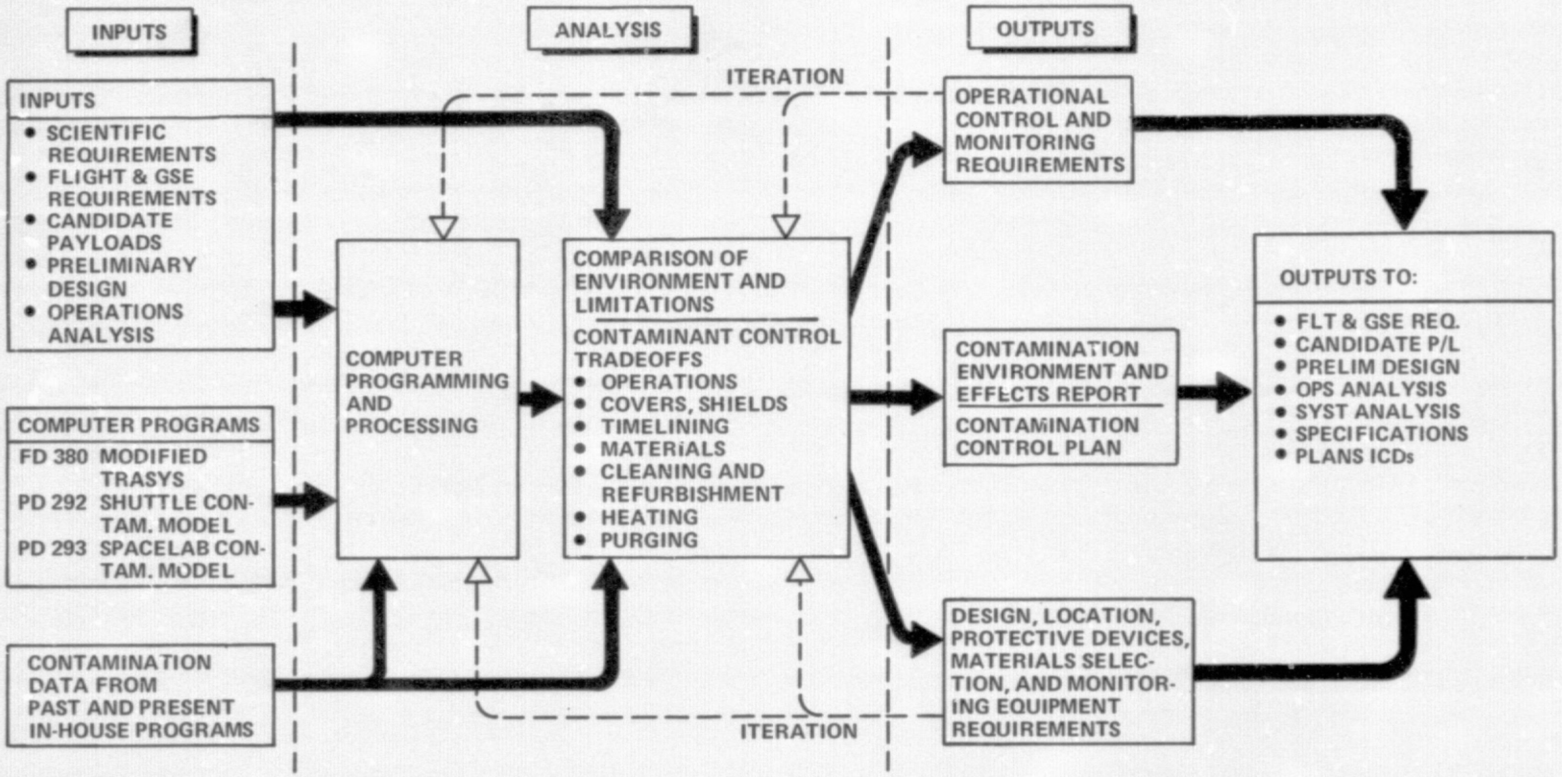


Figure III-7 Contamination Analysis Approach

Key elements of the control plan will contain data from the Phase B and other related studies and detailed instrument/systems analysis. When the analysis indicates that undesirable contamination conditions exist for an instrument, processes for reducing contaminant emissions and/or their harmful effects will be recommended. These recommendations and the environment description will provide guidelines for design and operational planning where contamination effects are considered intolerable. Subsequent design modification and changes in operations or equipment locations will be reassessed to comply with contamination limitations.

The main emphasis of the contamination analysis/control task will be to identify important design and operations requirements. These include hardware design and manufacturing, flight and ground operations requirements with special emphasis on nonmetallic materials selection, preferred instrument and support equipment locations, requirements for shielding and covers, instrument and contaminant source timelining and constraints, operation of protective devices, special test requirements, facility and vehicle cleanliness levels and controls, and cleaning and monitoring procedures and equipment.

The analysis approach illustrated is a proven process from other large space programs. Using this process, the contamination environment to be expected during specific ground and flight operations, considering all coincident contaminant source functions, will be determined and the consequent effect on contaminant sensitive surfaces assessed. Resulting trade studies will indicate preferred or most acceptable control processes.

The result of the analysis process, that is, the design requirements and operational constraints determined, will be reflected in the appropriate specifications, plans and interface control documents.

7. <u>Mass Properties Analysis</u> -- The mass properties effort for the AMPS design and development phase will involve the acquiring of mass property data and requirements, establishing the AMPS payload mass properties, maintaining and updating the mass property status throughout the program, and verifying by measurements, the mass properties of critical components and assemblies. The design and development mass properties flow diagram is shown in Figure III-8 and depicts the input, analysis and output relationships.

Review of existing data and acquisition of mass property data from instrument designers, component suppliers, Spacelab reports, Orbiter equipment reports, support equipment drawings and suppliers of MMSE will take place as the design phase is activated. Analysis of detail designs will provide additional data to be integrated with existing information to calculate the Orbiter payload cg at launch and return. The Skylab developed mass properties computer program (VD202) will be used during the preliminary and final design phases to provide a weight accounting base and integrated mass properties data capable of rapid

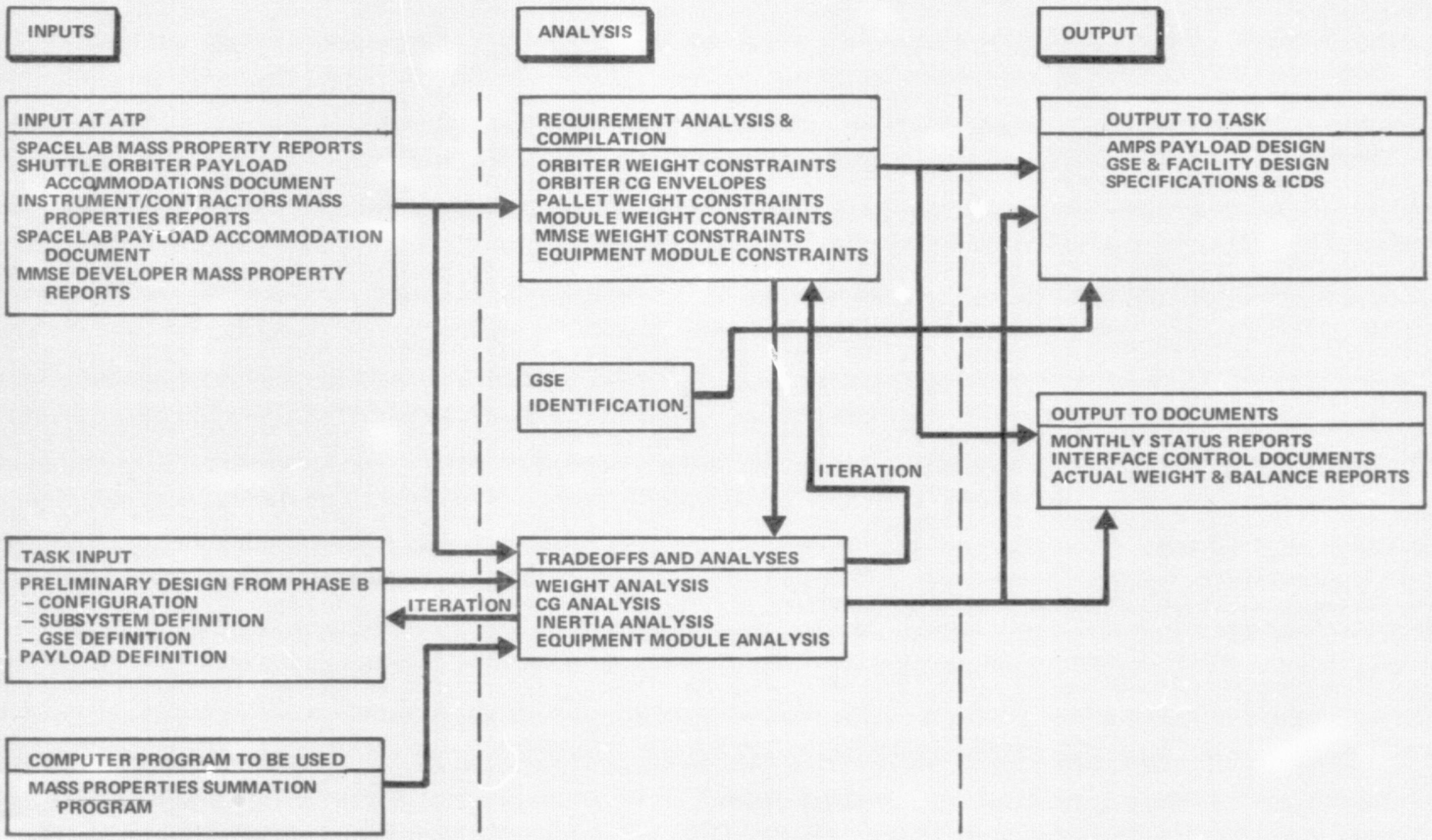


Figure III-8 Mass Properties Analysis Procedure

reaction to changes. Spin stabilized modules as proposed in the preliminary design study will require analysis to validate the proper spin moment of inertia ratios and to define the ballast requirements. Since deployed sensors and antennas are a part of this concept, investigations of the perturbations possible due to partial deployment will also be studied. Actual spin table verification testing will be controlled and monitored by the mass properties group. Abort and emergency jettison analysis will be performed to illustrate that the Orbiter can safely return under all foreseen conditions. Weight margins, based on experience and similar design concepts, will be assigned during the preliminary design phase to allow for potential growth and redesign situations.

Mass property status reports will be issued on a regular basis to provide input to performance, loads and strength analysis, GSE and facility design and design personnel. This data will also be utilized by instrument contractors and interface coordinators as part of their ICDs.

8. <u>Crew Systems Analysis</u> -- This task will perform analyses, studies and evaluations necessary to establish the AMPS payload crew operations requirements. Emphasis will be placed on optimizing the total crew involvement in achieving AMPS scientific and program objectives while minimizing program cost.

To define the total crew requirements, our plan is to concentrate the effort/analysis in four identifiable and interrelated areas such as, Workstation Design and On-Orbit Operations; Inflight Contingency; Stowage; and Crew Training. The analysis will make maximum use of available simulators and facilities to verify that the requirements defined are valid and obtainable. These requirements will be documented and maintained in a Crew Systems Requirements Document and used to support the design and development of the hardware.

Additionally, design analysis of the support systems will be performed to insure compatibility of crew tasks, crew interfaces, system design and hardware interfaces with the defined crew requirements and capabilities. Crew task analysis, operations plans, procedures, etc. will also be prepared under this task.

9. <u>Configuration Analysis and Control</u> -- This task will perform analyses, evaluations and trades to insure that the defined configuration will satisfy the science, experiments, instruments and program requirements and that it is the optimum configuration for the defined payload.

The defined configuration will be documented in drawings, layouts, system schematics, master parts lists, performance data specifications, configuration description documents, etc., and placed under configuration control.

Configuration control will assure a systematic evaluation, coordination and disposition of proposed changes to established baselines and

requirements. AMPS configuration control will be accomplished through a contractor Configuration Control Board (CCB). The CCB will assess the total impact of all changes and submit changes, as required, to GSFC for approval. Control will be exercised throughout the design, development, verification and operation phases of the program.

10. Design Reviews -- Design reviews such as PRR, PDR, CDR and crew systems reviews will be conducted to approve technical and program documentation that establishes hardware and software baselines. In support of these reviews we will prepare review schedules, agenda, prepare and close-out RIDs, prepare presentation material and provide co-chairman/team members as required.

In-house (contractor) reviews will also be held to review technical requirements, program status, changes and presentation material for other briefings requested by GSFC.

C. Specifications and ICDs

This section will define the approach to the generation and maintenance of specifications and ICDs during the AMPS Phase C/D. Figure III-9 illustrates the inputs, analysis approach and outputs for completion of the tasks. The key to this approach is the identification of a hierarchy of specifications, or specification tree. During Phase B, we developed a top level specification tree that will be used as the nucleus for generating the Phase C specification tree. Early identification and sanction of this tree is the key to avoiding costly overdevelopment of documentation.

Requirements will be baselined early for the first AMPS mission utilizing Phase B study results. System level and CEI specifications and ICDs will be updated for the first AMPS mission. Specifications and ICDs will be available for the PDR and CDR, with the final issue at the end of the design and development phase of the program. Thorough knowledge gained by the prime contractor in prior programs will be used in preparing and maintaining these documents to reduce costs.

System level specifications anticipated at this time are updates of the Mission Support Requirements Document (MSRD) and the AMPS Payload General Specification (APGS) and generation of a GSE Systems Specification and an AMPS Software Systems Specification.

Identification of contract end items is dependent on the design and integration process and responsibilities. We assume the prime contractor will be responsible for the CEIs for the FSE and GSE, and for the integration of subsystems with instruments. The instruments would previously have been delivered to the prime contractor under their own CEI specification as GFE.

The ICDs required during Phase C/D identified thus far are the AMPS to Shuttle, Spacelab and Instruments ICDs. Outlines for these ICDs were

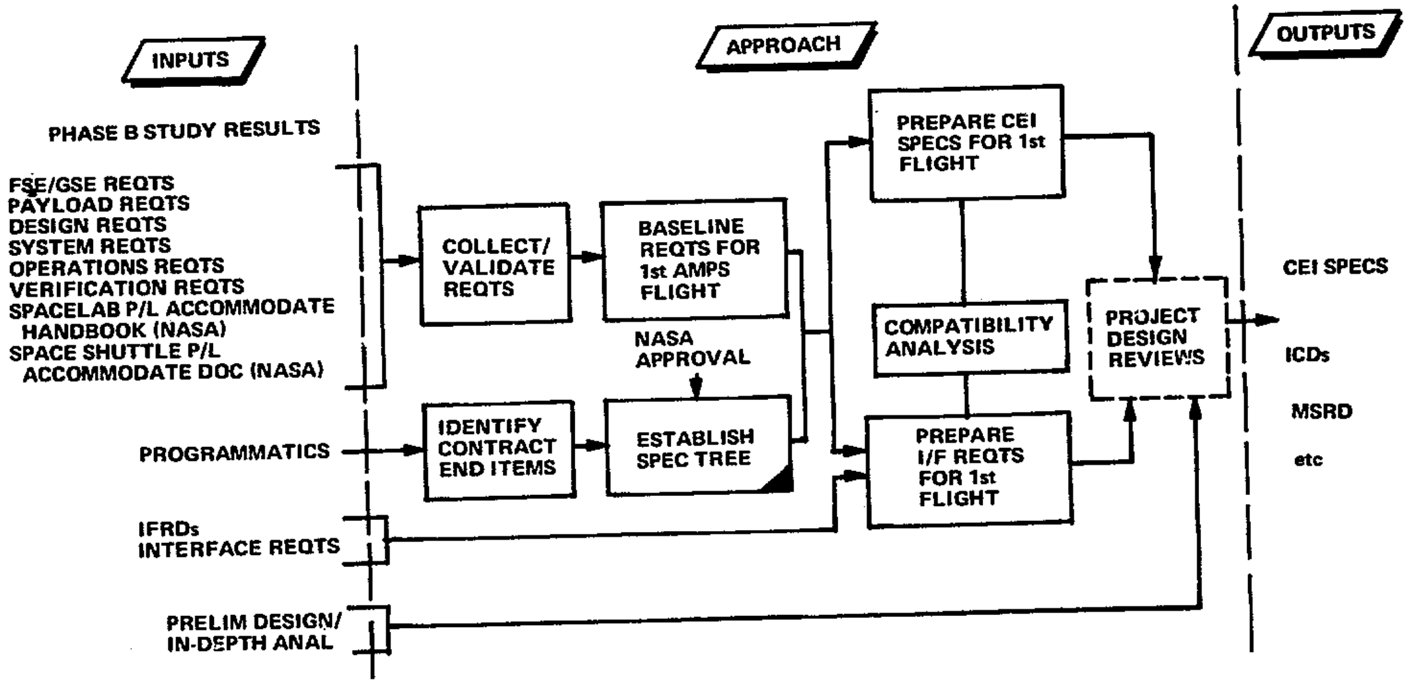


Figure III-9 Specification and ICD Generation Procedure

prepared during Phase B and they will be generated for the specific payload after baseline definition. The interfaces for the Space Shuttle and the Spacelab will generally be controlled by the Accommodations Handbooks with exceptions being incorporated into the ICDs. Instrument ICDs will be generated by the prime contractor with assistance from the instrument developer.

D. Instrument Requirements and Integration

The Instrument Requirements and Integration task includes:

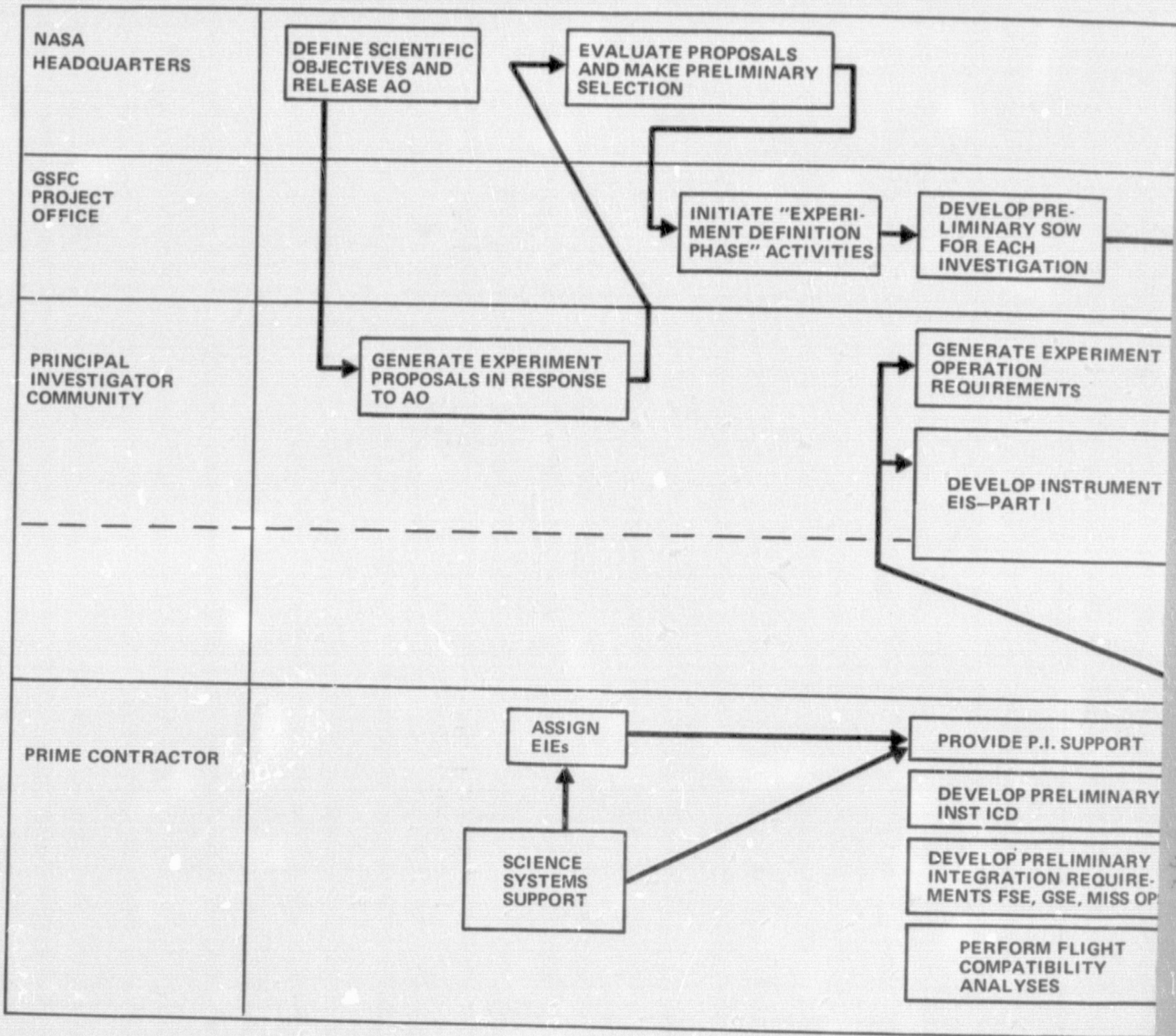
1) Liaison and support between the Principle Investigator the Instrument Developer and the prime contractor.
2) Scientific and engineering support to generate Experiment Operations Requirements and Instrument End Item Specifications.
3) Developing instrument interface and integration requirements such as power, data thermal, operations, test, GSE, facilities, software, etc.
4) Performing interface and compatibility analysis.
5) Preparing and maintaining Instrument Requirements, ICDs and Users andbooks.
6) Support to reviews, pertinent meetings and briefings.
7) Providing support during integration, test, launch, operations and data evaluation.

The approach to performing this activity will be to assign Experiment Integration Engineers (EIEs) backed by a dedicated science staff to each of the experiments or instruments. These EIEs will be selected on the basis of an appropriate background of training and experience to enable them to thoroughly understand the objectives and mechanisms of the planned experiment. These individuals will identify areas requiring trade studies and compatibility analyses and will work with the investigators to resolve problem areas and identify valid instrument and experiment requirements as early in the program as possible to assure the definition of an efficient and productive scientific mission.

The building blocks making up the integrated functional scientific mission consist of the individual experiment requirements and the definition of the required instruments. A schematic representation of the responsibilities and interaction is shown in Figure III-10.

1. <u>Experiment Requirements</u> -- The physical conditions and measurement data which form the basic experiment requirements will be developed into an implementation plan to identify the detailed engineering level requirements needed for mission integration.

Examples of the physical conditions are constraints on season for launch; orbit inclination requirements; position in orbit; lighting constraints; field-of-view pointing; location relative to ground stations; etc.



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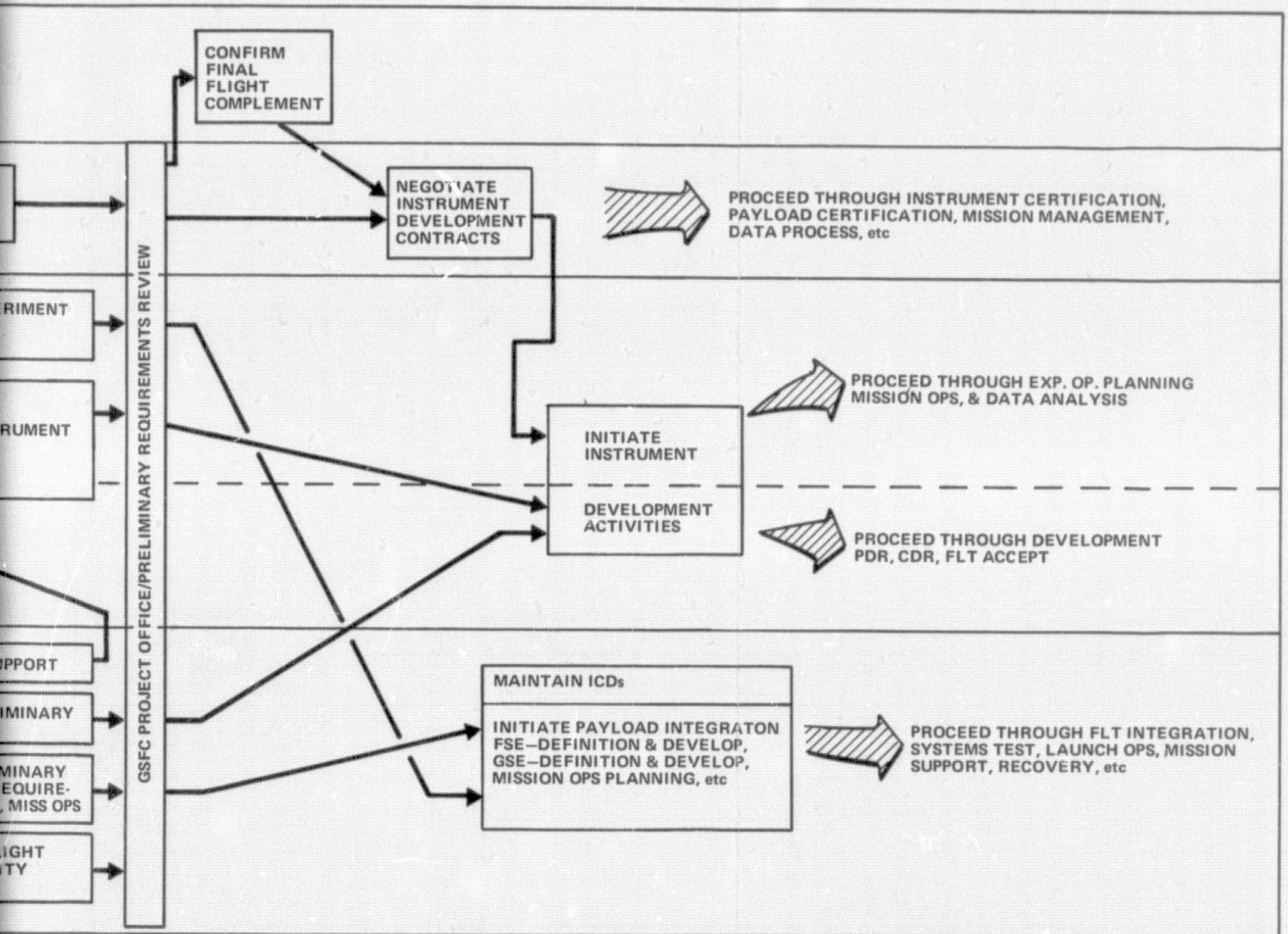

Figure III-10 Experiment/Instrument Responsibilities and Interactions

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Examples of measurement data are spectral radiance measurement from a specified source area; time profiles of laser backscatter signals; charged particle energy and pitch angle distribution; vlf wave intensity; etc.

It is the preparation of these implementation plans that the potential incompatibilities between experiments, carrier, crew and mission will be identified and resolved. The EIE, backed by science, system and subsystem support from the prime contractor will work in support of the Investigator during the development of these plans to provide insight into the capabilities and constraints of the spacecraft system and the possible interaction with other experiments. The EIE will identify alternative approaches for consideration by the Investigator and will act as a focal point in resolving incompatibilities. The results of this activity will identify requirements in the areas of mission operations and flight support equipment.

2. <u>Instrument Requirements</u> -- Prime contractor (EIE, et al) support will also be provided to the investigator/developer to define instrument requirements and to identify the constraints imposed by system interfaces and operational considerations that must be incorporated into the instrument design requirements. In this area, the EIE will interact with the investigator/developer to identify and develop an integrated set of instrument requirements. The instrument performance and design requirements will be documented in the Instrument End Item Specification for review and approval by GSFC prior to hardware fabrication.

3. <u>Requirements Documentation</u> -- The prime contractor will provide support via the EIEs to the investigator and/or developer to prepare the Experiment Operations Plan and Instrument End Item Specification and will prepare and maintain ICDs and the overall systems, ground, mission, etc. requirements contained as appendices to the MSRD.

4. <u>Reviews</u> -- The EIE will participate in the PRR, PDR, CDR and all other pertinent reviews and meetings, including test, checkout, mission operations, etc. during the succeeding stages of the program. He will provide the continuity and coordination between the investigator, developer and prime contractor to assure payload and experiment compatibility.

IV FLIGHT SUPPORT EQUIPMENT DESIGN AND DEVELOPMENT

This section summarizes the methods and techniques recommended for the design and development of the flight support equipment required to establish the AMPS laboratory in conjunction with the Spacelab/Orbiter capabilities and the possible instrument payloads foreseen for the future. The process, by which this design and development is accomplished, has been based on using a team concept where the responsibility for all phases of the program rests with the individuals initially selected. The communication between the major elements of the program -- program management, systems engineering and integration, hardware design and development (FSE and GSE), fabrication of hardware (FSE and GSE), software development and verification and test -- is established early in the Phase C/D planning period and maintained by a close working relationship of the team members.

Figure IV-1 presents a summary description of the required tasks and defines their interrelationships. This process is initiated in parallel with the Systems Engineering and Integration effort described in Section III. The experiments and candidate instruments, defined by NASA along with overall program design criteria form the basis for the initial analysis. As the preliminary systems analysis is accomplished, baseline payload descriptions along with mission parameters and systems level design criteria (reliability, quality assurance, safety, environments, etc.) will form additional input to the design and development tasks.

This description is general in nature and has been developed based on the type of tasks required for each of the subsystems defined for the AMPS laboratory. The design and development effort has been defined in terms of five separate task categories:

1) Requirements Analysis;

2) Subsystem Design Analysis;

3) Detailed Subsystems Design;

4) Subsystems Development;

5) Fabrication and Test Support.

The process is, of course, iterative in nature as shown in Figure IV-1. Only the more significant feedback loops are shown for the purpose of diagram simplification and clarity. None of the process steps is completely independent because of the impact of newly developed constraints on previous configuration decisions. Figure IV-2 portrays the approximate scheduling relationship between the task categories listed above and their relationship to major program milestones for AMPS Flight 1.

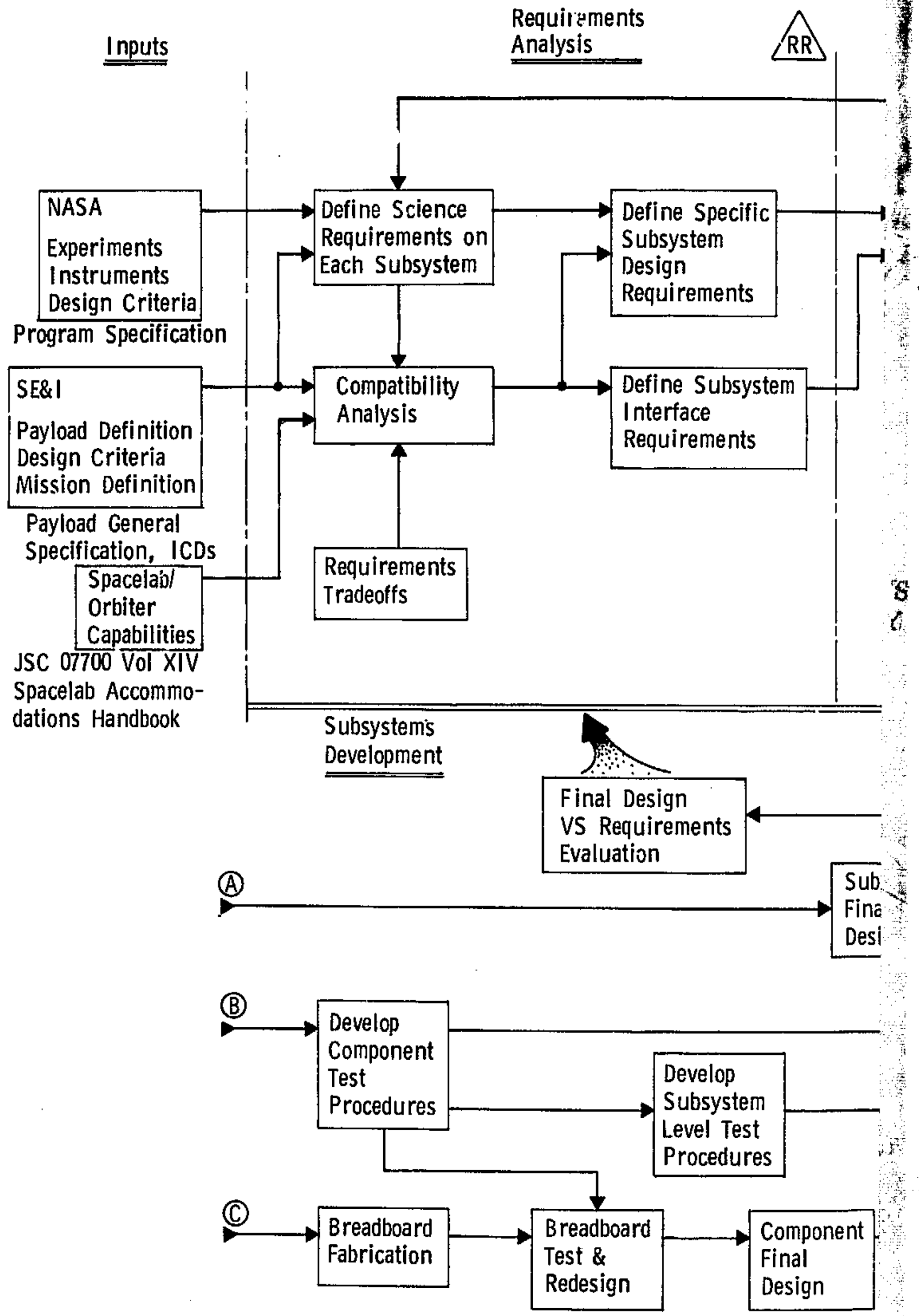

Figure 3-1 Flight Support Equipment Design and Development Process

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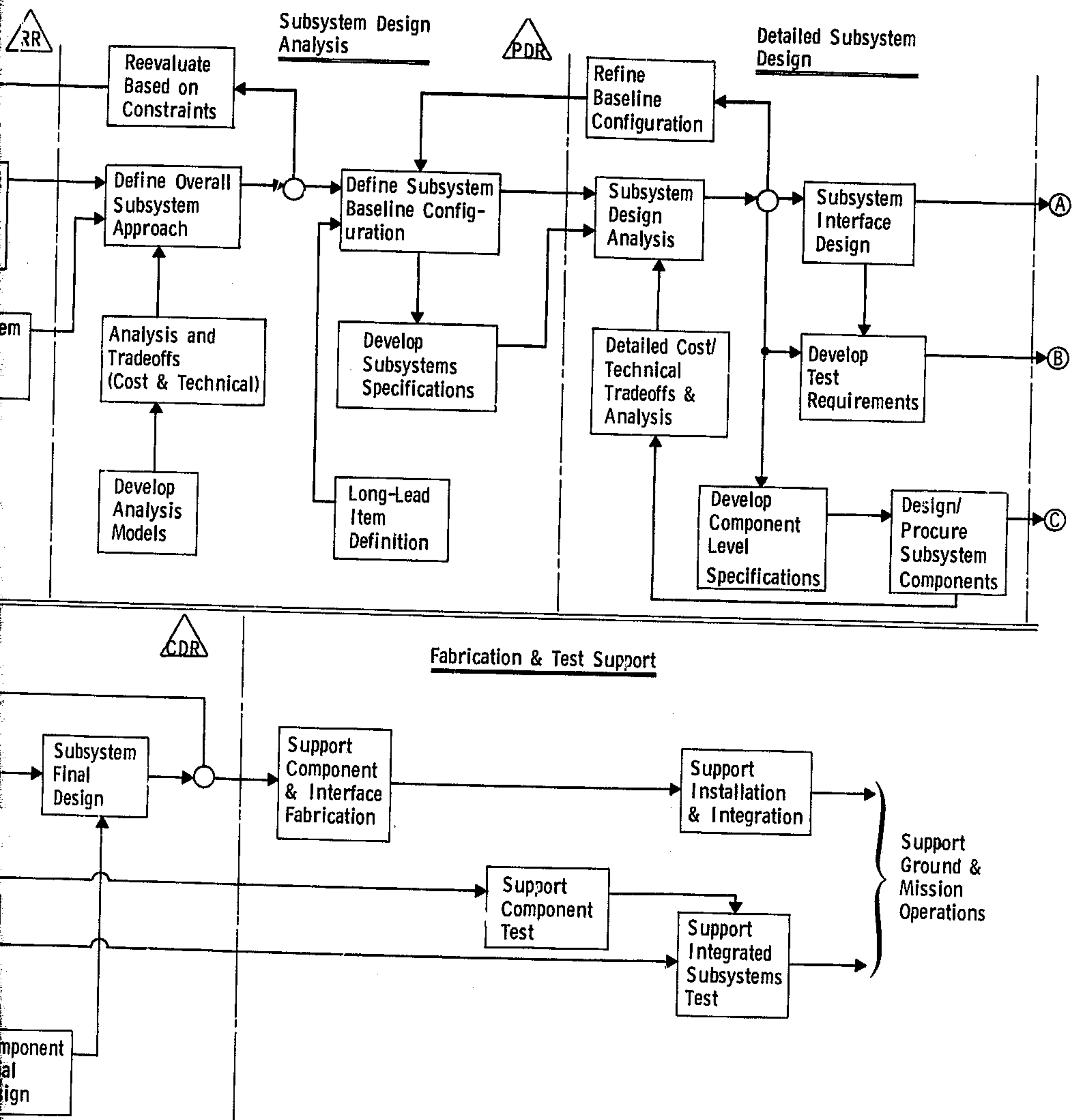

Figure IV-1 Flight Support Equipment Design and Development Process

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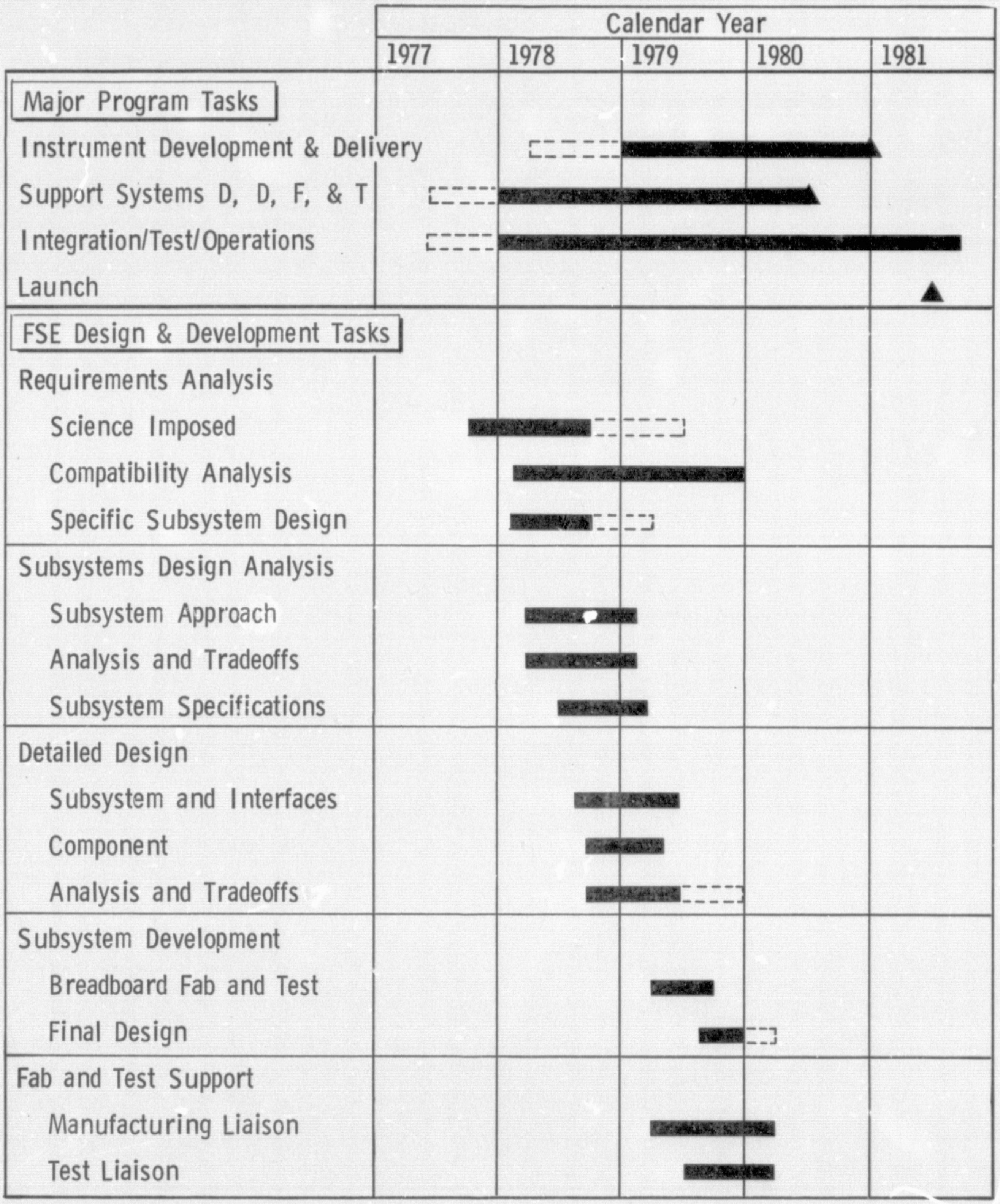


Figure IV-2 AMPS Flight 1 Design and Development Schedule

The time overlap between the various tasks indicates the iteration requirement as well as variable scheduling of different subsystems. The balance of this section will describe the approach to accomplishment of each of these task categories and conclude with a discussion of the development status for each of the individual subsystems foreseen for the AMPS laboratory.

A. Requirements Analysis

This task has been defined with the objective of determining the design requirements for support equipment necessary to supplement that capability provided by Spacelab and Orbiter. The starting point for this analysis is based on the assumption that Phase B definition studies have been performed, for a similar type of payload, and that a Payload General Specification is available along with an updated list of instruments to be considered. Selected AO responses will be used for design definition of the instruments. The accomplishment of this task will include the following steps:

1) Definition of subsystem support requirements for each instrument;

2) Comparison of available capability and instrument needs;

3) Definition of design and interface requirements for each payload unique support;

4) Definition of constraints needed to refine payload definition.

The initial definition of the science requirements imposed by individual instruments will begin at contract go-ahead. As the analysis proceeds, the results of parallel systems level analysis to define the overall payload and mission parameters will be integrated to form a total subsystem set of requirements for comparison to Spacelab and Orbiter provided capabilities. Table IV-1 portrays some examples of the type of requirements expected for each of the AMPS subsystems. Emphasis will be placed on combination of the specific instrument requirements with those developed for the payload and mission in terms of accommodating a complete scientific investigation rather than a series of instruments.

Comparison of the defined requirements with the capability provided by Spacelab and Orbiter is accomplished by performing compatibility analysis as shown in Figure IV-1. This analysis will lead to specific definition of the necessary subsystem support which cannot be supplied by the Orbiter or Spacelab. It will address, subsystem by subsystem, the interfaces with the instruments, Spacelab and Orbiter as well as the individual support requirements of the experiments. A considerable number of these interfaces and science requirements have been identified during Phase B studies. Therefore emphasis will be placed on validation

Table IV-1 Typical Instrument Requirements to be Defined

Subsystem	Requirements
Structures	Instrument Weight & Size Field of View Sensor Position Data
Thermal Control	Instrument Temperature Limitations
Electrical Power	Voltage, Current, Power Levels Grounding Constraints EMI Sensitivity
APCS	Orientation Pointing Accuracy Stability During Measurements Targets Alignment
Data Handling & Communication	Data Rates Data Types Real Time Needs Formats
Control and Display	Operations Functions (on, off, sequence, calibration, etc)
Deployed Instrument Support	Supporting Instrumentation Location and Accuracy of Sensors

of previous study results and development of the constraints needed to refine the science requirements and to aid in more detailed definition of each investigation. The subsystem compatibility analysis complements the system level analysis described in Section III. A close working relationship will be developed early in Phase C/D in order to assure an integrated, across-interface set of support requirements. Maximum use of Spacelab/Orbiter capabilities will be the prime goal of the analysis along with simplification of inter-vehicle interfaces. Trade-offs to optimize and reduce the payload unique requirements will be performed as part of this analysis. System level schematics, prepared as part of the SE&I effort will be used as a tool to validate the results. Cost minimization will be of prime importance throughout the program. Introduction of cost analysis at the beginning stages will be accomplished by assuring that maximum use of supplied capability and interface simplification goals are met.

The results of the compatibility analysis will be documented as a set of design requirements for each of the defined subsystems. They will also define the requirements which must be met at each of the interfaces with the Spacelab and Orbiter. Some examples of the expected results are summarized in Tables IV-2 and IV-3. Emphasis will be placed on developing an integrated set of requirements to set the stage for complete payload design analysis. These requirements will be presented to GSFC at the Requirements Review for detailed evaluation and updating.

The process of requirements analysis will be iterative in nature and is expected to continue on beyond the Requirements Review. Because of the previous analysis performed during Phase B studies, it can be considered as a refinement or validation effort. Reevaluation of the experiment/instrument requirements and definition is foreseen as the subsystem requirements indicate constraints or possible cost savings. Expected changes in experiments and instruments to meet science requirements and funding constraints will also create a need to redo portions of the requirements analysis. Update of the Payload General Specification will be initiated based on analysis results.

B. Subsystem Design Analysis

This task consists of the necessary effort to develop the laboratory baseline configuration for each of the defined subsystems based on the design requirements developed during the previous task. Specific emphasis will be placed on minimizing unique flight support equipment and where specific design is required, providing evolutionary capability to support downstream missions. Accommodation of future requirements will be through design margin and modularity to promote an add-on philosophy. The accomplishment of this task will include the following steps:

1) Definition of subsystem approach;

2) Analysis and trade-offs to support approach;

Table IV-2 Typical Support Subsystem Design Requirements

Subsystem	Design Requirements
Structures and Mechanisms	Instrument Position with Respect to Pallet Position and Stiffness for Deployed Sensors Emergency Ejection Criteria
Thermal Control	Instrument Temperature Limitations Payload Electrical Power Dissipation
Electrical Power	Total Payload Power Special Voltages and Frequencies EMC Criteria
APCS	Pointing Accuracies $> \pm 2$ Degrees Orientation with Respect to Pallet Surface.
Data Handling and Communication	Deployed Module Data Rates and Types Relative Position with Respect to Orbiter. Analog Data Bandwidths
Control and Display	Dedicated Control and Display Man-machine Interface Criteria
Deployed Instrument Support	Instrument Sizes and Weights Relative Position Data

Table IV-3 Typical Interface Design Requirements

Subsystem	Requirements
Structures	Maximum Loading at Pallet Hardpoints Pallet and Module Interface Configuration
Thermal Control	Spacelab Fluid Loop Specifications Connector Configurations
Electrical Power	Distribution Maximum Power Levels Grounding Criteria
APCS	Orbiter G&C Inputs/Outputs Spacelab Computer Configuration Spacelab Computer Software Criteria
Data Handling and Communications	RAU Interface Configuration High Rate Multiplexer Interface Definition Format Criteria
Control and Display	Rau Command and Data Interface Configuration Keyboard and CRT Configuration

3) Development of analysis tools;

4) Documenting the baseline configuration.

The definition of each of the subsystems will entail development of the optimum mix of Spacelab/Orbiter, unique payload support equipment, Labcraft type equipment supplied as GFE, and off-the-shelf equipment. Development of the subsystem approaches will be based on a total integrated design with emphasis on satisfaction of each of the scientific investigations proposed for the mission. The Orbiter and Spacelab capabilities are well defined and need only to be carried through as a major part of the design approach with continual evaluation of optimized usage as the subsystem approach is developed. The use of Labcraft type equipment, furnished as low cost standard GFE, will take first precedence to supply subsystem support not furnished by Spacelab Orbiter. Candidates for this type of equipment are pointing platforms, attitude control sensors, rate gyros, power supplies, thermal control canisters, transmitters, receivers, coders and decoders. The balance of the flight support requirements will then be evaluated for possible use of off-the-shelf equipment after which specific design specifications will be developed to input the detailed design phase. Special emphasis areas for this portion of the task include:

1) Initial payload design integration through preliminary layouts;

2) Combination of support requirements to fit single equipment designs;

3) Inter-subsystem interface optimization;

4) Standardization of instrument structural support designs;

5) Standardization of instrument interfaces;

6) Standardization of data handling equipment;

7) Design for minimum cost and complexity;

8) Incorporation of mission parameters and constraints.

As the subsystems approaches are developed, constraints which have been highlighted will initiate a reevaluation of the science/system/subsystem requirements and a refinement of the payload definition. Decisions which may effect instrument design, experiment implementation or instrument complement will be made at this time.

An integral part of the definition of the subsystem approach will be the backup analysis and trade-offs necessary to justify the selected design. The objectives of this portion of the task is to assure that the

design is technically sound, alternative methods for requirements implementation have been evaluated and that cost considerations have been given the proper priority. Trade study and analysis reports will be prepared for evaluation by GSFC. Some of the more significant analysis foreseen for Phase C/D include:

1) Design integration trade-offs (individual pallet and integrated payload);

2) Instrument grouping trade-offs to satisfy experiment requirements;

3) Instrument/subsystem interface standardization (payload versus instrument provided);

4) Thermal control approaches (active versus passive);

5) Power distribution for individual instruments (payload supplied control and protection versus instrument provided);

6) Modification of off-the-shelf equipment versus new design;

7) Evaluation of the cost and complexity impact of using standardized Labcraft equipment;

8) Development of harnessing techniques to best fit quick turnaround and ground operations requirements.

This list forms the nucleus of the types of analysis which will be accomplished prior to baselining the subsystem configurations. Additional analysis will be performed to resolve specific problems as they arise. Each of the analysis will support the decision making process with respect to alternative selection, cost reduction potential, use of available equipment or designs and simplification of the configuration. Selection criteria and weighting factors will be introduced at the beginning of the analysis along with the definition of success criteria.

Trade-offs and analysis, as discussed above, will be enhanced through the use of various tools foreseen to support baseline design of the subsystems. Subsystem schematics, which expand on the overall system level drawings developed as noted in Section III, will be used to define and optimize the concepts as the analysis is completed. They will also be used to assess the impact of design changes as they are identified. Layout drawings - pallet, assembly and subassembly - will be used to develop equipment/instrument arrangements and interference problems. Automated equipment lists will be generated and will form a basis for an orderly accounting of items to be purchased or designed. These lists will be developed to include data such as weight, size, power, potential procurement sources, etc., in order to provide data for detailed electrical

power, thermal control, and mass properties analysis and to support make or buy decisions. In addition to this type of analysis tool, mathematical models will be developed and used to accomplish complex technical computations necessary to define detailed design criteria and evaluate the adequacy of the design. The models identified for Phase C/D Spacelab payloads include:

1) Mass properties computations and listing program;

2) TRASYS Program for external environment, radiation, interactions and coupling computation;

3) MITAS Program to calculate predicted equipment temperatures;

4) Integrated thermal control subsystem model (combine fluid loop, cold bias, and canister with external environment);

5) Vibration analysis model (mode shapes and frequency determination to support dynamics and pointing control);

6) Loads analysis model to predict instrument and equipment loads and to set structural design criteria (model must interface with GFP provided Orbiter and Spacelab models);

7) Pointing platform analysis models to validate pointing accuracy and stability performance of the candidate platforms;

8) Electrical energy management model to develop power usage profiles and to assist in optimization of mission power management.

All of the computer programs listed above are available and have been used to support various aerospace projects. Phase B type definition studies included development of some of the models as a demonstration of their feasibility for specific Spacelab payload projects. Examples of preliminary models which are in operation include mass properties for solar physics, astrophysics and AMPS payloads; three body model for pointing and stability analysis of the SIPS and MPM pointing platforms and integrated thermal control model for AMPS. These models will require modification and expansion based on the specific configuration to be developed for Phase C/D implementation but the methods have been established and verified. The goal for development of all models and other analysis tools will be in support of the detailed design, subsystem development, test and operations phases as well as baseline configuration definition.

The results from the first three steps in this task will then be documented in the form of a baseline laboratory configuration leading to the preliminary design review. The objectives of this review will be to validate the design approach and its capability to meet the

scientific and program requirements. Problem areas which require program management decisions will be identified along with potential alternatives for solution. This review will consist of a presentation of the configuration and the supporting rationale. In support of the review, more detailed splinter sessions are envisioned for indepth discussions of each subsystem and the backup analysis data to support these sessions will include:

1) Subsystem and assembly schematics;

2) Layout drawings;

3) Equipment lists by subsystem;

4) Long lead item definition;

5) Trade-off and analysis reports

6) Backup data from mathematical models;

7) Subsystem level specifications.

Completion of the preliminary design review and resolution of the resulting action items will initiate the detailed design phase of the program. It is of primary importance that long lead items be identified by this point in the program to assure that downstream schedules are met. Subsystem specifications are also scheduled at this time to support early initiation of design or procurement of the long lead items. These specifications are considered as working papers within the contractor's house and are used to expand the Payload General Specification as required.

C. Detailed Subsystem Design

The objective of this task is to expand on the baseline configuration and perform the detailed design to the point where fabrication can begin. Of primary importance for management of the design and development phase, at this point, is the team approach outlined earlier. Subsystem lead engineers, responsible for the initial design definition, will continue with the detailed design and carry through to fabrication and test of the overall subsystem. As the process proceeds toward completion, they will be collocated with manufacturing and test personnel and have the authority to make decisions which impact the design and manufacture of the equipment. Detailed designers, assigned for individual componenets at this time, will assume responsibility for that component and, as a team member, provide on-the-spot decisions regarding the component.

This task develops the baseline configuration to meet the detailed specifications prepared as part of the previous task. The overall

subsystem design will be expanded and verified through detailed analysis and trade-offs leading to the definition of detailed design specifications for procured and complex components and to the definition of specific interface design features as shown in Figure IV-1. Special emphasis areas for this portion of the task include:

1) Early processing of detailed designs for long lead items to meet program schedules;

2) Commonality of design to the greatest extent possible,

    a) Standard truss/platforms for instrument mounting,

    b) Standard pallet hardpoint attachments,

    c) Standardization of RF and data handling components,

    d) Standardization of electrical and plumbing connectors;

3) Early detailing of instrument interface design to support parallel instrument development;

4) Continuing use of the engineering tools and mathematical models to definitize and validate the detailed design. Updates and expansion is envisioned to meet the requirements of this level of design;

5) Continuing reevaluation of the impact of design decisions on the baseline configuration and design requirements;

6) Update of higher level specifications to incorporate the results of design decisions.

7) Evaluation of component design compatibility with the subsystem using the available tools and models;

8) Definition of test requirements in parallel with the design to insure a design for ease of test philosophy;

9) Optimization of design through indepth cost and technical trade-offs and analysis;

10) Close coordination between subsystem areas to assure compatible inter-subsystem interfaces.

At the completion of this task, all the design documentation necessary to initiate the fabrication of the complete laboratory will have been prepared. The type of documentation foreseen includes:

1) Engineering drawings (including bill of material and parts),

   a) Detail manufacturing,

   b) Subassembly,

   c) Assembly;

2) Detailed top level layouts;

3) Updated specifications;

4) Test requirements (subsystem and component);

5) Final analysis and trade study reports;

6) Mass properties estimates and calculations,

   a) Individual component breakdown,

   b) Integrated payload;

7) Updated interface control documents;

8) Updated systems and subsystem level schematics;

9) Component level schematics;

10) Wiring diagrams;

11) Harness drawings.

Preliminary analyses during the Phase B AMPS Study have resulted in definition of equipment needed to support the strawman science payloads defined by the AMPS scientific working group. Table IV-4 presents a listing of the equipment required over and above that provided by Spacelab and Orbiter for the first AMPS flight. This table highlights all contractor provided equipment and candidate GFE equipment supplied as Labcraft because of multimission usage potential and is included to provide program sizing data.

D. Subsystems Development

The objectives of this task are to fabricate and test breadboards and other development type models and to prepare the test documentation to the point of readiness for checkout of the flight equipment. The preliminary analyses accomplished during the Phase B Study indicates that only a limited number of components would require construction of models. Table IV-4 shows that much of the equipment is off-the-shelf or provided GFE

Table IV-4 AMPS Flight 1 Equipment List

Subsystem	Nomenclature	Location	Quantity	Make Buy GSE	Development Status
Structures	Base mount bracketry	Pallet 1,2,3	-	Make	New
	Truss/platforms	Pallet 1,2,3	8	Make	New
	Brackets	Pallet 1,2,3	-	Make	New
	Individual Truss Numbers	Pallet 1,2,3	-	Make	New
Special Mechanisms	L/L Locks - OB[illegible]PS	Pallet 3	1	Make	New
	Emergency Jett-MPM Platform	Pallet 3	1	GFE	-
	Capture Rlease Device	Pallet 2	1	Make	New
	Capture Release Device	Pallet 2	1	Make	New
	L/L Locks-NIR Spec	Pallet 1	1	Make	New
	L/L Locks-NIR Spec	Pallet 1	1	Make	New
	Emergency Jett-MPM Platform	Pallet 1	1	GFE	-
	Capture Release Device	Pallet 1	1	GFE	-
	PIC (For Holddown Nuts)	Pallet 1	6	Make	O/S
	Holddown Ordnance	Pallet 1	18	Buy	O/S
TCS	I/F Plumbing Kits	Pallet 3	1	Make	New
	Thermal Curtain	Pallet 1	1	Make	New
	Thermal Curtain	Pallet 2	1	Make	New
	Thermal Curtain	Pallet 3	1	Make	New
	Exp Heat Exchanger-LIDAR	Pallet 3	1	Buy	New
	TCS Pump-LIDAR	Pallet 3	1	Buy	O/S
	Coolant Filters	Pallet 3	6	Buy	O/S
	MPM Canister-NIR Spec	Pallet 1	1	GFE	-
EPDS	Cable Set	Pallet 1	1	Make	New
	Cable Set	Pallet 2	1	Make	New
	Cable Set	Pallet 3	1	Make	New
	Cable Set-Module to Pallet	Pallet 1	1	Make	New

Table IV-4 AMPS Flight 1 Equipment List (Continued)

Subsystem	Nomenclature	Location	Quantity	Make Buy GSE	Development Status
EPDS (Continued)	Cable Set-Module	Module	1	Make	New
	Cable Set-SIPS to Instrument	Pallet 2	1	Make	New
	Pulse Power Supply-LIDAR	Pallet 3	1	Buy	New
	Pulse Power Supply-Acceler	Pallet 3	1	Buy	New
	Peaking Battery	Pallet 3	1	Buy	O/S
	Electrical Dist Unit	Pallet 1	1	Make	New
	Electrical Dist Unit	Pallet 2	1	Make	New
	Electrical Dist Unit	Pallet 3	1	Make	New
APCS	SIPS Platform	Pallet 2	1	GFE	-
	Two Axes Gyro Package	Pallet 2	1	GFE	-
	Two Axes Gyro Package	Pallet 2	1	GFE	-
	3 Axes Gyro Package-OBIPS	Pallet 3	1	GFE	-
	3 Axes Gyro Package-NIR Spec	Pallet 1	1	GFE	-
	MPM Platform-OBIPS	Pallet 3	1	GFE	-
	Fixed Hd Star Trker-II-7-10	Pallet 2	1	GFE	-
	MPM Platform-NIR Spec	Pallet 1	1	GFE	-
	Fixed Head Star Tracker-NIR	Pallet 1	1	GFE	-
Data Handling & Communication	FM Module	Module	1	Buy	O/S
	Sensor Interface Box	Pallet 2	1	Make	New
	Sensor Interface Box	Pallet 2	1	Make	New
	Sensor Interface Box	Pallet 1	1	Make	New
	Sensor Interface Box	Pallet 3	1	Make	New
	Analog Recorder	Module	1	Buy	O/S
	Transient Recorder	Module	5	Buy	O/S
	Switching Panel	Module	1	Make	New
	Video Recorder	Module	1	Buy	O/S

Table IV-4 AMPS Flight 1 Equipment List (Continued)

Subsystem	Nomenclature	Location	Quantity	Make Buy GSE	Development Status
Data Handling & Communication (Continued)	Command Transmitter	Pallet 2	1	Buy	O/S
	RF Multiplexer	Pallet 2	1	Make	New
	Wide Band Receiver	Pallet 2	2	Buy	New
	Conical Antenna	Pallet 2	1	Make	New
Control & Display	C and D Panels	Module	1	Make	New
	C and D Panels	Module	1	Make	New
	C and D Panels	Module	1	Make	New
	TV Monitor	Module	1	Buy	O/S
	Oscilloscope	Module	1	Buy	O/S
	C and W Sensors-Pressure	Pallet 1	12	Buy	New
	C and W Sensors-Temperature	Pallet 1	8	Buy	New
Deployed Instrument Support	Beam Diagnostic Package	Pallet 2	1	Make	New
	Wide Band Transmitter		2	Buy	O/S
	Command Receiver		1	Buy	O/S
	RF Multiplexer		1	Make	New
	Antenna, Stub		1	Buy	O/S
	Cable Set-Beam Diag Package		1	Make	New
	Power Supply		1	M/B	O/S
	Strip Heaters		1	Buy	O/S
	Multilayer Insulation		1	Make	New
	Subcarrier Oscillator Assy		1	Buy	O/S
	PCM Programmer		1	Buy	O/S

Table IV-4 AMPS Flight 1 Equipment List (Continued)

Subsystem	Nomenclature	Location	Quantity	Make Buy GSE	Development Status
Deployed Instrument Support (Continued)	Beam Diagnostic Package (Con't)	Pallet 2			
	Command Decoder		1	Buy	O/S
	Deploy Device (III-2)		1	Make	New
	Capture/Release Interface		1	Make	New
	Launch Lock-Vector Mag		1	Make	New
	Basic Structure Package		1	Make	New
	Gas Release	Pallet 1	6	Make	New
	Command Decoder		1	Buy	O/S
	Antenna, Stub		1	Buy	O/S
	Command Reciever		1	Buy	O/S
	Cable Set		1	Make	New
	Power Supply		1	M/B	O/S
	5 M/S Delta V Eject		1	Make	New
	Gas Release Ordnance		2	Buy	O/S
	PIC		1	Make	O/S
	Multilayer Insulation		1	Make	New
	Strip Heaters		1	Make	New
	Environmental Sensing Package	Pallet 1	1	Make	New
	TM Transmitter (S-Band)		1	Buy	O/S
	Antenna, Conical		1	Make	New
	Antenna, Conical		1	Make	New
	Command Receiver		1	Buy	O/S
	Diplexer/Splitter		1	Buy	O/S
	PCM Programmer		1	Make	New
	Command Decoder		1	Buy	O/S

Table IV-4 AMPS Flight 1 Equipment List (Concluded)

Subsystem	Nomenclature	Location	Quantity	Make Buy GSE	Development Status
Deployed Instrument Support (Continued)	Environmental Sensing Package (Continued)	Pallet 1			
	Cable Set-ESP		1	Make	New
	Power Supply-ESP		1	B/M	O/S
	Strip Heaters		1	Buy	O/S
	Multilayer Insulation		1	Make	New
	Capture/Release Interface		1	Make	New
	For ESP - Antenna		1	Buy	O/S
	For ESP - Antenna		1	Buy	O/S
	Launch Lock-Vector Mag		1	Buy	O/S
	For ESP - Probe		1	Buy	O/S
	JII-2 Sensor Drive		1	Buy	O/S
	Spin Table - ESP		1	Buy	New
	ESP Structure		1	Make	New
	Release Ordnance + Cont		1	Buy	O/S

and it appears that the most likely candidates for breadboards or prototypes are the special mechanisms. These models will be built in engineering laboratories under the direction of the component engineer member of the team. Testing will be accomplished to preliminary procedures prepared for flight equipment testing. Drawing, specification and procedure control will be accomplished by redlining as modifications are necessary and preparing as-built drawings to move forward to flight equipment fabrication.

Particular emphasis will be placed on preparing all levels of test procedures during this period so as to be prepared for flight equipment qualification and acceptance testing. Test requirements definition will have been completed as part of the previous task and will input the development of both subsystem level and component procedures. The type of tests to be performed will be based on the program test philosophy as discussed in Section VII.

Completion of the breadboard testing and necessary component redesign will provide input to the final design update in preparation for the Critical Design Review (CDR). The interface, component and subsystem designs will be reevaluated to assure compliance with the payload scientific requirements and all systems, subsystem, and component level specifications will have been updated. The CDR will consist of a presentation of the system/subsystem level design along with the supporting rationale. Problem areas will be highlighted and alternatives presented to promote early resolution. Individual splinter sessions for each subsystem will be held to assure an indepth evaluation of the design to provide contractor/NASA agreement prior to the start of flight equipment fabrication. The documentation for this review is as specified in the previous task and will be updated to meet the final design definition prior to the review.

E. Fabrication and Test Support

The manufacturing and testing plans for the Phase C/D AMPS Program are discussed in Sections VIII and VII, respectively. The objective of this task summary is to discuss the relationship of the engineering effort required to support these program phases. The documentation prepared as part of the previously described tasks forms the baseline around which control will be implemented during the fabrication cycle. An experimental shop approach is envisioned because of the limited quantity of items of a specific design to be built. Fabrication will be based on direct use of engineering drawings with a minimal amount of specific manufacturing documentation. The drawings will be formally released prior to the start of manufacturing and change control, of an informal nature, will be initiated at this time. Drawings and specifications will be redlined as changes become necessary with as-built drawings scheduled after completion of fabrication

The team concept becomes most important at this stage of the program development. Collocation of engineering and manufacturing control personnel will promote the onsite real-time decisions required to enhance cost and schedule performance. The responsible engineer also has direct access, because of his continuing design participation, to the tools and supporting personnel required to perform the analysis to validate each design change. He will also assure that overall system impacts have been addressed so that changes do not effect system/instrument compatibility. The fabrication of interface interconnecting equipment will also be monitored during this period with continual verification with instrument and flight support equipment design in progress through the subsystem lead engineer.

Verification testing, at both component and subsystem level, will progress under the direction of the component and subsystem engineers. Procedures prepared during the previous task will be redlined and updated after completion of the testing. It will be the responsibility of the design engineers to assure that all equipment meets its specifications and to initiate redesign where necessary. He will also follow-through higher level testing until the completed payload has been verified and provide design consultation during the integration phases of the payload at KSC.

The engineering support during the Level IV, III, II, and I integration cycles at KSC, Level IV integration at the contractor's plant and mission operations is not defined in this section. Following sections of this document discuss these phases of the program. However, the same team approach will be used whereby selected design team members will be assigned to follow-through the operations phases and provide consultation and any necessary redesign for the laboratory.

F. Development Status

During the Phase B Study, typical payloads were defined and a preliminary design accomplished which led to a definition of types of flight support equipment required to support AMPS type of missions. Table IV-4 includes a listing of this equipment. This section summarizes the development status of the subsystems based on the analyses completed and is presented here to provide data to assist in the assessment of cost and technical risks for Phase C/D.

1. Structures and Mechanisms Subsystem -- The structures and mechanisms subsystem effort for the design and fabrication phase can be grouped into the following three major tasks: Support Structure Design and Analysis (including instrument support, equipment support, and integrated equipment modules), Mechanism Design, and Structural Testing.

Support structure design, based on AMPS configuration layouts, uses established design and fabrication techniques. Three types of instrument

support structure proposed are truss, platform, or direct type structures. Truss support structure involves welded tubular members with machined interface pads that extend between instrument interfaces and the pallet hardpoints. The platform approach uses a structural grid composed of tubular or extruded shapes that is mounted from the pallet hardpoints directly or by tubular members. The direct mount concept uses machined brackets or fittings between the instrument and pallet hardpoints. Each of these concepts will use 6061 aluminum alloy material because of the availability, cost, and corrosion resistance. Design margins can be increased to decrease risk and reduce testing. These design approaches and material selection make the proposed instrument support structure design a low risk area.

Complex design and load interfaces occur at the pallet hardpoints when two or more support structures share these fittings. On the aft pallet for Flight 1, there are interfaces involving three instrument support structures and as many as eight structural elements. The coordination and integration problems associated with shared mounting interfaces could lead to design and cost problems unless a solid interface control is established.

Integrated equipment module design concepts involve welded frames as primary structure and provide removable access panels and secondary structure for equipment support. With the current instrument weights and design requirements, this conservative design approach using standard materials should be adequate for the final design phase.

The mechanisms effort does involve some complex design problems. However, all designs investigated are achievable from a technology standpoint. The problems anticipated are those in keeping costs down and defining reusable designs rather than unique equipment for each application. The proposal to use the same family of capture/release mechanisms for all the deployed modules on Flights 1 and 2 is the type of approach needed to satisfy these goals.

Qualification structural testing involves many decisions that can cause schedule and cost variations. Prototype or protoflight test philosophy decisions, along with decisions on testing at component, subsystem, or integrated pallet level, as well as choice of test, are factors which affect the program plans, costs and schedules. The recommended structural test approach presents two alternates; one prototype and one protoflight. A final decision on which program to use will depend on payload requirements including multiple flights, low cost, and maximum reliability.

2. <u>Thermal Control Subsystem</u> -- The Orbiter Spacelab/AMPS payload consists of numerous instruments and support equipment with diverse power and thermal requirements. The AMPS thermal design matches the diversity of the requirements by use of Spacelab hardware and standard thermal

control techniques to the maximum extent. The AMPS thermal design employs an active thermal control loop, pallet thermal curtain, cold-biased thermal design, environmental canister and open cycle cryogen.

The AMPS active fluid loop design makes maximum use of Spacelab hardware (coldplates, plumbing) to minimize cost and design risk. Recent studies considering the diversity of instrument layouts have shown that it is often required to mount coldplates on the instruments as opposed to the standard pallet locations. An alternative approach uses experiment-dedicated heat exchangers for concentrated heat loads such as the LIDAR.

Thermal analyses have shown that a thermal curtain enclosing the pallet is required for solar-inertial attitudes. A low α/ϵ multilayer insulation structural (MLI) curtain in conjunction with the pallet loop minimizes the temperature variations of the coldplates components.

A cold-biased semi-passive thermal design approach has been baselined for components that are mounted, fully or partially, outside the pallet thermal curtain. A low α/ϵ coating (S-13G paint or similar) is used to maintain equipment at relatively low temperatures for hot conditions and thermostatic heaters are provided for cold case operations.

Standard environmental canisters need to be developed to provide relatively constant temperatures for critical instruments. Current candidate approaches include the GSFC small-instrument pointing system (SIPS) heat pipe canister, an MSFC miniature pointing mount canister that uses Skylab Apollo telescope mount hardware, and a JSC AMPS instrument module system (AIMS) that uses coldplates coupled directly to the pallet loop.

Several AMPS instruments require cryogenic temperatures and the most viable thermal design approach uses stored cryogens as an integral part of the instrument. The approach is within the state-of-the-art, but additional work is required to investigate techniques to charge the instruments if solid cryogens are used.

The AMPS TCS utilizes state-of-the-art hardware to minimize cost and design risk. The materials used are Multilayer Insulation (MLI), Silver Coated Teflon (SCT), electrical strip heaters and thermal-control paint. All items have been used in previous in-house spacecraft programs, except SCT. SCT has been used successfully in many spacecraft and has demonstrated superior performance (low solar UV degradation).

Design risk can be decreased by a continual verification of the TCS capability to meet the instrument and FSE requirements. The design will be verified for all mission phases using a systems level thermal math model which has been developed to a preliminary level during Phase B studies. This model has been developed for use with the existing thermal analysis computer program, MITAS and absorbed external heat fluxes will be calculated using the TRASYS program. Both programs have been

used extensively on Viking and Skylab and the techniques for coupling the programs to the AMPS TCS model have been validated.

A major related effort is coordination with the instrument manufacturers. Thermal math models of instruments with close temperature tolerances will be constructed to generate thermal sensitivity data to identify critical thermal parameters. Instrument manufacturer's thermal math models will be integrated with the AMPS systems level thermal models as required. Thermal analysis results will be utilized to verify and establish component qualification temperature limits. In addition, as a part of the thermal system integration task, environmental heat fluxes will be generated and provided to the instrument manufacturers as design boundary conditions.

The major cost and technical risk for the TCS is that of the canister design. Presently, two of the canisters; SIPS and MPM, are envisioned as being provided GFE as Labcraft or multimission support equipment and are in the planning stages. Changes in planning or scheduling of this equipment may require design of a replacement canister. The complexity and potential high cost of this type of equipment requires early identification and more detailed design evaluation to determine program impact.

3. Electrical Power and Distribution Subsystem -- The electrical power and distribution subsystem uses Spacelab provided power sources and distribution harnesses for a significant percentage of the required payload power support. Very little cost or technical risk is foreseen in developing this portion of the laboratory. Harnesses will be designed and fabricated using existing space qualified wire and connectors. The distribution boxes required to route power and signal circuits from Spacelab pallet junctions to the instruments will be simple design using off-the-shelf hardware and will be extensions of previous designs. Interfacing of the integrated harness will be given prime consideration to assure minimum redesign as the payload is assembled. Early identification of connector types and detailed pin assignments through the Interface Control Documents will promote ease of integration. Standard available connectors will be selected to reduce costs and consideration will be given to common procurement of both halves of the interface.

Battery power supplies required for deployed instrument support modules and to provide peak power usage above that supplied by Spacelab/Orbiter, have been flown in space on other programs and are readily available. Standard sizing and the accommodation of down-stream requirements for recoverable modules will be given consideration as potential program cost reductions.

The major cost and technical risk for this subsystem is the design and development of the high voltage power supply to provide high energy storage and high voltage pulse power to some of the instruments. High voltage distribution, protection of adjacent instruments, and safety

of personnel will be significant factors. The capacitor approach to energy storage, recommended for the early AMPS flights, impose a weight penalty which may not be acceptable for future flights because of the requirement for considerably higher energy storage. Again, early identification of the approach to be taken is required in order to assess program impact.

4. Attitude and Pointing Control Subsystem -- The basic premise in the area of pointing platforms is that the number and types of units required to accommodate the pointing accuracy and stability requirements for a given flight will be Government Furnished Equipment (GFE). This assumption applies to both types of platforms currently under investigation; namely, the Small Instrument Pointing System (SIPS) and the Miniaturized Pointing Mount (MPM). In addition to studies by various interest groups, both of these platform configurations have undergone intensive investigation by the Experiment Pointing Mount (EPM) working group under JPL auspices and as directed by NASA Headquarters. Their conclusions and recommendations have been presented to Headquarters with final disposition pending.

Preliminary design and analyses to date for the SIPS and the MPM have proven conceptual feasibility. Moreover, these analyses have demonstrated that the performance capabilities of these platforms exceed the current AMPS payload pointing requirements. However, as payload requirements become more stringent, as anticipated they will, the performance requirements can be levied to a greater extent on the control sensors and to a less proportionate extent on the pointing platforms. It is extremely impractical to develop a dedicated pointing platform(s) for individual payloads with the concomitant design, development, test and costs required. Therefore, the baseline assumes use of GFE platforms with possible compromise of instrument pointing requirements.

The development of the SIPS concept is based upon existing technology with no advancement in the state-of-the-art required. The conventional design of this pointing platform requires precise balance of an instrument payload to achieve highly accurate pointing stability performance. This does not present any obstacle as it is estimated that a 500 kg instrument can be mass balanced to within 0.2 cm. Sufficient lead time must be allocated for delivery since, as previously stated, only a conceptual study has been completed. While the technical risk is considered low in development the SIPS, development lead time is of the essence.

The MPM is being developed as a general purpose instrument platform and also serves to complement the SIPS and the Instrument Pointing System (IPS) under development by the European Space Agency (ESA). The small size and weight of the MPM lends itself to being very adaptable to volume constraints in the Orbiter payload bay. It can also be modified to accommodate boom tip and antenna control pointing requirements for future missions. Costs and development risks for the MPM are

minimized since the concept makes maximum use of existing hardware. Current planning includes refurbishing the remaining ATM Star Tracker assemblies and electronics to convert them into highly accurate instrument pointing mounts.

5. Data Management Subsystem -- The design and development approach to the AMPS data management system is based on the following criteria:

a) Usage of equipment developed on other programs

b) Low cost for equipment mounted on throw-away diagnostic packages

c) Maximum usage of Spacelab/Orbiter capabilities

The resulting data management system which consists of AMPS provided hardware plus the Spacelab CDMS has tried to minimize new development and complexity, using or upgrading off-the-shelf equipment whenever possible. Table IV-4 lists the type of equipment foreseen for AMPS missions in addition to that provided by Spacelab.

The Spacelab digital data bus is centered around a MITRA 125 computer and uses the same mass memory as developed for the Orbiter computer. Equipment of new design are primarily in the Spacelab CDMS and includes the I/O, RAU high rate multiplexer and the CRT display units. These components will be required to undergo a complete design and development program. Of these, the RAU and the high rate multiplexer have direct interfaces with the AMPS instrument and interface compatibility will be of major concern. The RAU processes analog, discrete and serial digital data and also provides discretes and serial digital commands to an instrument. During the instrument design phase it will be necessary to analyze the interface circuitry for compatibility, ground loops, failure modes and data rates to ensure total system operations.

Perhaps the most complex of the new design will be the high rate multiplexer and its demultiplexer. In the AMPS system all science data will be routed through this multiplexer and as such represents a potential single failure point. The development of this design and, in particular, its instrument interface, will require close scrutiny. Such characteristics as word length, bit rate, synchronous or asynchronous data transfer, buffering and formatting must be identified and compatibility analysis with the instrument accomplished to preclude interface incompatibility. Although the experiment I/O unit is one step removed from a direct instrument interface, it is the focal point of controlling all traffic through the Spacelab CDMS and any constraints or limitation in the resultant equipment capability could affect payload operations. Close coordination with the developer of this unit, as well as timely interface agreements through the ICDs, will be implemented to reduce risk.

Of the AMPS provided equipment shown in Table 3-4, no new design is required. The primary task will be on the area of environmental requalification. The analog magnetic tape recorder represents a high cost item and, although a basic design exists, redesign of mounting configuration, replaceable tapes, control circuitry design and environmental tests will be required. FM modules are required, both inside the Spacelab and outside on the various diagnostic packages. Voltage controlled oscillators (VCO) and discriminators that operate up to 4 MHz are required and existing designs are available. VCOs will require repackaging to aerospace standards. However, FM discriminators and transient recorders located inside the Spacelab module can be packaged more like avionics equipment with its larger volume, weight, air cooling requirements instead of the standard aerospace design.

Commonality of equipment design is stressed for the PCM encoders and command decoders used in the diagnostic packages. Since most of these packages will be non recoverable, low cost becomes a significant factor. The selected PCM encoder and command decoders are of existing design, have been used on other aerospace programs and have the necessary flexibility to accommodate the varying payload requirements. The modularity and flexibility of the encoder provides for varying bit rate, programmable format, valuable input channels for analog and digital measurements. The command decoder is also of modular design and is easily customized to the needs of each payload.

6. <u>Communication Subsystem</u> -- This discussion of communications development status will deal only with the hardware requirements identified to support communications with deployed packages such as the ESP and gas releases. Remaining requirements deal with air-to-ground communications which is the responsibility of the Orbiter and, as such, do not form a part of the AMPS program design responsibility.

RF components required to communicate with deployed packages consist of transmitters, receivers, antennas, and multiplexers/diplexers. It has been possible to satisfy the identified requirements with conventional FM systems and RF link designs, which is also consistent with low cost systems, particularly where non-retrievable packages are concerned. In the same context it has not been necessary to resort to sophisticated modulation or spectrum spreading techniques.

A commercial line of transmitters and receivers is available to satisfy much of our hardware needs. Previous applications have resulted in hardware specifications in the areas of temperature, shock, and vibration which meet or exceed Orbiter payload specifications. However, it may be necessary to supplement these specification data with limited acceptance tests in the area of EMI or outgassing characteristics. In addition, it may be appropriate to review hardware parts lists and request some changes in either components or materials which are more suitable for the Orbiter environment. One manufacturer of these components considers this to be feasible, resulting in only a modest cost impact.

Within this area of hardware, only one possible development problem exists. One application requires S-band, wideband FM receivers with a data bandwidth of 4 MHz, which are not commonly available. The requirement is not unique to ground receiving equipment, but exceeds current characteristics of space hardware. One option to pursue is increasing current bandwidth designs from 1 MHz to 4 MHz. Indications are that this is a feasible concept, and that some manufacturers are already working in that direction, but this is still considered a soft development area.

The remaining components in the system include standard S-band stub and conical spiral antennas and diplexers/multiplexers. These may not be available off-the-shelf with the required characteristics, but are copies of hardware previously built and used for space applications. Therefore, no development problems are anticipated.

7. Control and Display Subsystem -- The control and display subsystem utilizes both payload unique and Spacelab supplied hardware and software. The Spacelab provided capability through use of the CRT, alpha-numeric keyboard and data bus appears to satisfy most of the payload requirements as defined today and does not effect technical or cost risk.

The payload unique C&D hardware comprises dedicated panels, an oscilloscope, and a TV monitor. The dedicated C&D panels are conventional designs used previously in other manned space programs such as Skylab, Apollo, etc. The components comprise toggle and rotary switches, light annunciators, and digital displays. Prior experience has shown the risk in developing this hardware is very low.

Oscilloscopes which meet the AMPS payload functional requirements and are compatible with Spacelab physical and functional requirements can be obtained in commercial versions from several major manufacturers. Modification of the hardware will be required in order to meet environmental and safety requirements. The extent of these modifications require detailed analyses and have not been determined at this time, adding some development risk for the program.

The AMPS TV monitor resolution requirements are unknown at this time due to the lack of detailed instrument (OBIPS) definition. If a 525 line system will suffice, then a copy of the Orbiter CCTV could be utilized with minimum development risk. However, if other non-standard resolution requirements are imposed, then the development risk discussion for the oscilloscope applies; i.e., the modification and qualification of commercial hardware.

8. Deployed Instrument Support Subsystem -- Development status for each of the deployed modules are discussed under each of the subsystems addressed above. The concept was developed around grouping of instruments into functions which can best be performed when deployed

as a package and requires new design for the several modules required for the AMPS flights. Although each module is different and requires a unique design, cost and technical risk should be minimal since most of the structure and components are well within the state-of-the-art. Possible exceptions to this are noted above.

V GROUND SUPPORT EQUIPMENT DESIGN AND DEVELOPMENT

This section will include the Ground Support Equipment program analysis and planning required to support the AMPS Phase C/D Program. GSE requirements, plans, and implementation approaches will be developed to a level sufficient for the design, and development and integration phases of the AMPS subsystem and instruments.

A. GSE Requirements Analysis

The GSE Requirements Analysis will proceed in the manner developed during the AMPS Phase B Study as shown in Figure V-1. Various items will be supplied as input information to initiate the AMPS Phase C/D GSE Analysis. AMPS Phase B Systems Analyses, primarily the Technical Summary and Mission Support Requirements Documents, will form the basic input data. Additionally, Space Shuttle and Spacelab Accommodations Documents will provide Ground and Mission Operations Requirements, and existing or planned GSE as specified in the Launch Site Accommodations Handbook, the Spacelab GSE Allocations Documents, etc., will be available as potential candidate items.

Using this information, we will develop a detailed ground operations flow for each integration site (Levels IV, III, II, and I) and for the maintenance and refurbishment activities sites currently being considered -- i.e., at the prime contractor and at KSC. Once each AMPS ground operations function has been developed, we will identify the tasks required to perform each of these functions. Task activities will fall into categories such as transportation, receiving and inspection, installation, test, etc. With the tasks identified, the GSE requirements will then be generated, which will enable us to identify the GSE by its generic type. The next phase is to compare these generic requirements to the GSE that is existing or that is planned for MMSE, Spacelab or Shuttle. While performing this comparison, we will examine the schedules to ascertain the availability of equipment when it is required by AMPS. The result will be a total list of GSE, some which already exists and other items which must be supplied by the AMPS program.

The process is an iterative one as is shown by the feedback loop and by the nature of the job. As iterations take place, the analysis will go to a deeper more detailed level, which will then identify the GSE design requirements.

1. GSE Groundrules -- In order to develop the GSE generic requirements, it is necessary to bound the entire problem with a set of GSE groundrules. The following groundrules were generated to support the AMPS Phase B Study and will be baseline for the Phase C/D.

a) Design, development, test, transport, support and handling GSE for instruments and FSE will be used as applicable

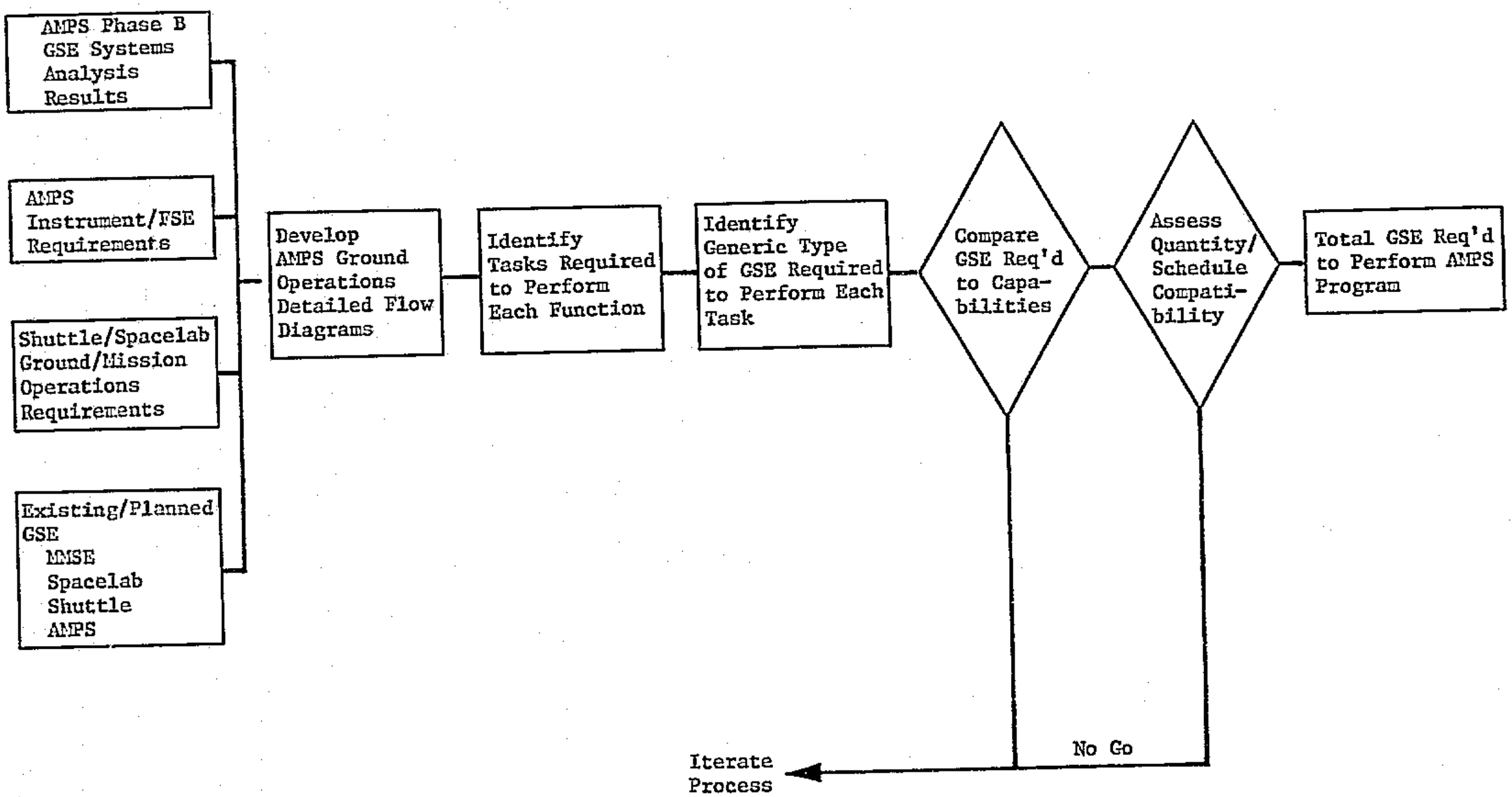


Figure V-1 GSE Analysis Functional Flow Diagram

throughout the ground operations cycle, and, wherever required, GSE built by the developing contractor will be delivered to support the planned activity.

b) GSE identified as MMSE or commercial equipment will be used to support AMPS testing at all levels in preference to developing special GSE.

c) GSE for transportation and handling of pallets and racks will be provided by Spacelab or MMSE.

d) GSE must support development, test, transport, storage, launch preparation activities, both online and off, and maintenance and refurbishment activities.

e) The AMPS prime contractor will provide that GSE not available from the developer which is required to support Level IV and subsequent activities.

f) Existing facilities will be used wherever possible. Prime contractor facilities will be used for Level IV activities.

g) No special handling or support equipment will be provided by AMPS for alternate site landing.

h) No special handling or support equipment will be provided for post flight operations to remove film or magnetic tape from the payload prior to landing +12 hours, i.e., normal vehicle access in the Orbiter Processing Facility (OPF).

i) GSE design will be compatible with the planned AMPS payload evolutionary approach and as such shall not require redesign and build between flights but will require only necessary update modifications.

j) GSE required for integration activities will be designed for use in a clean room environment.

k) GSE which is shipped between facilities with the FSE or instruments shall be cleaned and bagged prior to movement.

l) Access GSE from the Payload Changeout Room to the AMPS/Spacelab Payload interface connections to support unique payload operations will be provided GFP from KSC. Unique payload GSE required to support the instruments or FSE during this time will be provided by AMPS Prime Contractor.

m) The OPF will provide payload handling GSE necessary to support all AMPS payload requirements in that facility, i.e., hoist

capabilities to 65,000 pounds (29,483.5 kg) with a 15 foot (4.57 m) diameter and a 60 foot (18.3 m) length.

n) Calibration testing will be minimized after the development contractors acceptance tests are completed and no calibration tests will be permitted after the payload final instrument alignment activities are completed in the KSC Spacelab Processing Facility.

2. Task Identification -- For each instrument, flight support system and for integrated systems, various tasks will be identified. Tasks are anticipated to include but not necessarily be limited to manufacture, transportation, receiving and inspection, handling, assembly, installation, interface verification, calibration, servicing, storage, instrument/system integrated tests at various integration levels, alignment and mission simulations.

Tasks will be identified in many cases by trade studies which will compare the optimally lowest cost for the most effective task approach. Trade studies of this nature will of course be carried on by many disciplinary specialists, e.g., instrument specialists, test, operations, program planners, cost estimaters, ground support equipment specialists may share in the give and take inputs and decisions of a trade study.

3. Generic GSE Definition -- This phase of the GSE requirements definition will be initiated with the tasks as identified in Section V-A-2 above and conclude with the generic GSE requirements identity for the entire AMPS Program. The method used to accomplish this activity will be to list all of the requirements for each instrument, flight support equipment (FSE) item and integrated systems necessary to accomplish the task. After listing the separate requirements, a grouping analysis will be performed which will combine the requirements into categories. By categorizing the requirements, the GSE will be sized. An example of this technique would be to list the weights of each instrument, FSE item, and integrated systems items. The items could then be combined into small packages not requiring lifting slings, light, medium and heavy packages. Packages with similar sizes and weights would give us the generic requirements for lifting slings needed to support the AMPS Program.

4. Comparing GSE Requirements with Capabilities -- This phase of the GSE analysis finalizes the requirements definition phase. A comparison is made of the entire list of generic GSE requirements necessary to support the AMPS Program versus the capabilities of GSE existing or planned by the Shuttle, Spacelab or MMSE. Upon completion of this activity, the entire list of AMPS GSE will be defined; it will be divided into items to be supplied by other programs and items to be built by the AMPS Program.

5. GSE Trade Studies -- GSE trade studies will be performed comparing various technical approaches to ascertain which is the most cost

effective and still technically adequate. Trade studies will be coordinated with all the technical disciplines of the AMPS Program.

B. GSE Planning Approaches

The GSE planning during the Phase C/D program will be initiated with the results of the first iteration of the requirements analysis phase. This activity will coincide with the instrument, FSE contract's ATP. Planning documentation will be generated so that all contractors and NASA cognizant employees are able to maintain program visibility. Planning will consist of scheduling the various instrument, FSE prime contractor, and launch site activities to ascertain that all of the requirements will be fulfilled by the planned GSE. Details of the planning schedules will include the number of GSE items for a particular function, as well as the logistics planning to ensure the GSE availability for this function.

The GSE designs will be coordinated with test planning, ground operations, instrument development and safety personnel to be certain the proper functions are being exercised, that all specifications are being met, and all safety considerations for testing are satisfied.

As the program develops, GSE regularly scheduled meeting will take place on a monthly basis during Phase C and bimonthly during Phase D. These meetings will ensure close coordination between the contractor and NASA personnel and enable efficient cost effective management response to problem solving. Detailed schedules of the GSE and problem areas will be documented to provide visibility to the other program elements.

An example of a currently planned AMPS GSE milestone schedule is presented in Figure V-2. The GSE will be provided by a variety of sources as discussed in the following paragraphs and will initially consist of that equipment defined during the Phase B Study as depicted in Table V-1.

1. Development Contractor Supplied -- Most of the GSE required for the AMPS instrument and flight support equipment integration will be provided by the development contractor. Designs of the development contractor therefore must take into account the complete use of the equipment through the entire ground program and not just at his facility. To this end, the prime contractor will review the instrument contractor's GSE required for field use. A similar review of the GSE Acceptance Test and Data Package will be performed by the prime contractor to be certain that all functions are adequately covered. For example, if an instrument is handled by facility slings, the data package would have to identify clearly the GSE sling attach points and any constraints on handling.

Typical instrument and flight support equipment GSE anticipated consists of electrical test sets, calibration equipment, cryogen kits, alignment kits, protective covers and so on.

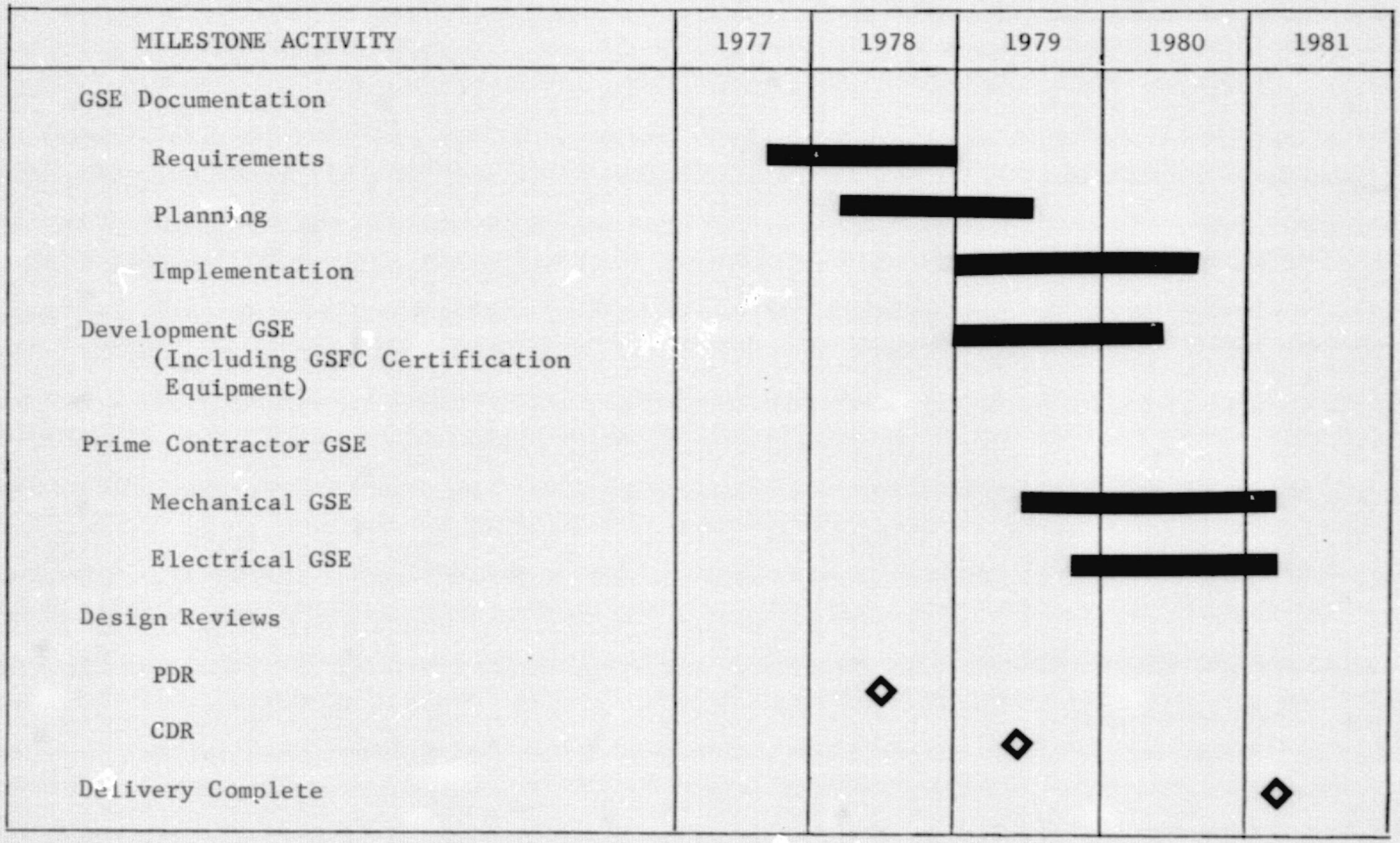


Figure V-2 AMPS GSE Milestone Schedule

Table V-1 AMPS/GSE/Facility/Task Requirements Matrix

Task	GSE/Facilities Required	Location: Developer	Level IV	Level III	Level II	Level I	Supplier
Transportation	Shipping Containers/ Plastic Bags	X	X				Developer
	Environmental Sensing/ Servicing Kit	X	X				Developer
	Transporter						
	Instruments, FSE	X	X				Developer
	Pallets, Racks	X	X	X			Spacelab/MMSE
	Spacelab/Pallet				X	X	MMSE
Receiving & Inspection	Facility Airlocks		X	X	X		Facility
	Clean Rooms	X	X	X	X	X	Facility
	General Purpose Test Equipment	X	X	X	X	X	Facility
Inventory/ Storage	Bonded Storage Areas		X				Facility
	Bonded Clean Rooms		X				Facility
Installation/ Handling	Facility Cranes		X	X	X	X	Facility
	Slings						
	Instruments/FSE	X	X				Developer
	Pallets, Racks		X	X			Spacelab
	Spacelab/AMPS				X	X	MMSE
	Handling Fixtures						
	Instruments, FSE	X	X				Developer
	Pallets, Racks		X	X			Spacelab
	Spacelab/AMPS				X	X	MMSE
	Pallet Simulator		X				Prime Contractor
	Instrument Covers		X	X	X		S/L, Prime Ctr.
	Instrument/FSE Alignment Kit	X	X				Dev., Prime Ctr.
	Optical Alignment Kit			X			Spacelab
	Optical Cleaning Kit	X	X			X	Dev., Prime Ctr.
	Rack & Floor Installation Kit			X	X		Spacelab
	Pallet Mate/Demate Kit			X			Spacelab

Table V-1 AMPS/GSE/Facility/Task Requirements Matrix (Con't)

Task	GSE/Facilities Required	Location: Developer	Level IV	Level III	Level II	Level I	Supplier
Access	Pallet Segment Floor Covers		X	X	X		S/L, Prime Ctr.
	Module Seg. Floor Covers				X		Spacelab
	Pallet Workstands		X	X			Prime Contractor
	P/L Hor. Access Kit				X		S/L, MMSE
	Instrument Access Kit		X	X	X		S/L, Prime Ctr.
	Int. & C/O Stand			X	X		Spacelab
	PCR Access Kit					X	S/L, Prime Ctr.
Interface Verification	Power/Services	X	X	X	X	X	Facility
	Power Cond. Units	X	X				Developer
	GSE Cables	X	X	X	X	X	All
	EMI Diag. Equip.		X		X		S/L, Prime Ctr.
	Service Kits						
	Freon	X	X	X			Facility
	Gaseous Nitrogen					X	Facility
	Liquid Helium		X	X	X	X	Facility
	Gaseous Neon		X	X		X	Facility
	Leak Check	X	X	X			Facility/MMSE
	Mag. Field Generator		X		X		Prime Contractor
	PIC Test Kit		X				Prime Contractor
	Computer & Anc. Equip		X	X	X		GSFC
	GSE Software	X	X		X		S/L, Dev., P. Ctr.
Integration Tests	Vibro/Acoustics						
	Instrument Systems		X				Prime Contractor
	Pallet Level		X				Prime Contractor
	Thermal Vacuum						
	Instrument Systems	X	X				Dev., GSFC, P. Ctr.
	Instrument/FSE Cal.	X	X	X			Developer
	Instrument/FSE Data Readout	X	X	X			Developer
	Simulators						
	CSS or Equivalent		X				S/L, Prime Ctr.
	OIA			X	X		Spacelab
	Spacelab ATE			X	X		Spacelab
	LPS				X	X	Launch Site
	Level IV Test Sets		X				Prime Contractor

2. Prime Contractor Supplied -- Some GSE required for integration activities of the instruments and FSE will be better supplied by the prime contractor. The type of equipment the prime contractor will supply pertains to integrated instrument systems or integrated pallet activities. In this category would be mechanical GSE such as alignment kits between FSE and instruments, access platforms, protective covers and electrical GSE such as a Level IV integration functional test set consisting, for example, of I/O and interface electronics, digital multiplexer simulator, a measurements and command interface panel, CRT and keyboard, etc.

3. GSFC Supplied -- The GSFC will supply some GSE necessary at their Certification Facility and the IBM 370 computer and its associated software for instrument sequences. The prime contractor will coordinate with GSFC personnel to be certain that any delivered items will be compatible with the Denver facility.

4. Other GFE -- A large majority of the GSE required for transportation and integration activities will be supplied by the Spacelab, Shuttle, and MMSE as GFE.

Transportation equipment including the low-boy trucks and integrated pallet shipping containers will be supplied by MMSE and/or leased by the AMPS Program. Equipment for pallets and racks during shipment and facility handling will be supplied by the Spacelab Program.

Equipment required during KSC Level III, II, and I testing will be supplied by the Spacelab, Orbiter and MMSE and will include items such as the Core Segment Simulator, Orbiter Interface Adapter, the Launch Processing System, and the large workstands. The AMPS prime contractor will assist GSFC in arranging for use of this equipment by preparing schedules which show AMPS need dates for each piece of equipment. The prime contractor will also review utilization schedules for the equipment and compare these schedules to AMPS needs. Any schedule conflicts will be brought to the attention of GSFC.

VI SOFTWARE DEVELOPMENT

This plan describes the activities required to develop, evaluate and deliver AMPS operational software. It identifies the phases, schedules, documentation, organization, facilities and supporting software required. It defines roles, responsibilities, methods and techniques to be used when developing AMPS software. This plan applies to all elements of software to be developed including: (1) mission planning software; (2) prelaunch integration, test and launch software; (3) AMPS operational flight and ground control software; and (4) STS AMPS support software requirements. The main objectives are to delineate the prime contractor's role in this activity, and to clarify interfacing contractor/agency roles.

The AMPS software development activity is somewhat unique in that it consists largely of applications software that is operated by executive systems developed elsewhere. The Spacelab program provides an executive system, and some applicable modules, for both the flight and EGSE computers. Compilers, editors and other development tools are also to be provided by the Spacelab Program. The AMPS contractor must provide application modules that are compatible with this system. Complete control documentation must be evolved in cooperation with the European Space Agency (ESA) to clearly define the applicable interfaces and thus minimize the problems of integrating the complete system. In the case of the AMPS/STS interfaces, it is anticipated that the applications software will be written by the STS contractors. The AMPS requirements documents will be implemented by the STS contractors, and validation testing will be performed at the major system (Spacelab/STS) level. The Payload Operations Control Center software will be developed in conjunction with GSFC, building on a base of existing spacecraft control software. The AMPS software development, then, is more deeply involved with interagency and intercontractor integration than many developments of similar scope. Control of this integration is a key issue in AMPS software development planning.

Three aspects of this software development plan seem most significant. First, consider the role developed for the prime contractor. He is responsible for the bridge between the prescribed capabilities of the Spacelab software system (for example) and the requirements of the AMPS scientific experimenters. His effectiveness as a coordinator is the key to the successful development of AMPS software. Secondly, a system of control has been evolved that will fortify the prime contractor's role. This control is implemented in a system of control documents (plans, requirements documents, design and test specifications, and interface control documents) that are maintained by formal but efficient procedures. A software change control board approves changes internal to the software development process in an expeditious manner. Changes whose effects go beyond software to hardware, user procedures, et al, are controlled at the major configuration control board level. Finally, a unique Software Development Laboratory (SDL) is planned for the prime contractor's facility. This SDL will house

an IBM 370 host for software development tools and operational computer simulation. This host will be interconnected with experiments/instrument developer's facilities. This facility will provide the prime contractor with the capability to implement the activities controlled by the documentation system described.

A. General Development Requirements

The general layout of the AMPS support software development will follow the standards and practices that have been developed at Martin Marietta and in the industry in the past. The general layout will be modified as required to fit the particular circumstances of the AMPS program. Structured programming and careful attention to module interface specifications permits a top-down development that will minimize the number of problems to be encountered in testing of the integrated system.

Basically this development approach for computer program evolution will follow seven distinct phases as outlined in the subsequent paragraphs.

1. <u>Definition Phase</u> -- During this phase the software developmental and test plans are finalized. Conceptual functional design and allocation are performed, and preliminary functional requirements are produced and documented. The System Requirements Review (SRR) provides management visibility required to evaluate progress.

2. <u>Requirements Phase</u> -- The requirements phase starts with the SRR and concludes with the System Design Review (SDR). Project planning is finalized and customer comments are incorporated. Functional requirements are finalized and system level trade studies are performed. Programmer procedures outlining the techniques and conventions are finalized. For every design requirement, a corresponding test requirement is generated. Development and requirements verification of new applications modules are effected. The result of the requirements phase will be a clear documented agreement (in the form of a functional requirements specification) between the customer and the developer as to the operational capabilities of the system.

3. <u>Preliminary Design Phase</u> -- During the preliminary design phase, overall design concepts are identified including sets broken down into packages, packages broken down into modules, and modules broken down into compilation units. Detail design of all system files and data base structures is performed. System level flow charts are developed showing interfaces between systems, sets and packages. System, set and package tests are identified. This phase builds a solid framework for the detailed design phase, and documents that framework in the set design specification and preliminary test specifications. The progress achieved is reviewed at the software Preliminary Design Review (PDR).

4. <u>Detailed Design Phase</u> -- The detailed design phase takes the system design specification and expands on it to the point where a programmer may start coding. Detailed flow charts are developed at the package, module and compilation unit levels. This phase is comparable to developing the engineering drawing for release to manufacturing in a hardware program. The design specifications describe the programs in complete detail, including a complete description of all input/output functions, all interfaces, all processing functions, all data base elements, diagnostics, storage allocations, flow charts, subroutines, timing budget, coding language and structure. Individual test procedures are identified. The software Critical Design Review (CDR) is held after completion of the software design specifications developed in this phase.

5. <u>Build Phase</u> -- The build phase is primarily a coding phase which starts at the completion of CDR and is completed at the Test Readiness Review (TRR). The software is developed to the point where it is ready to undergo formal testing. Sufficient informal testing is performed during the build phase to give the coders confidence that they are delivering quality coding. Test procedures and users guides are developed concurrently with the coding process.

6. <u>Test Phase</u> -- The test phase begins with the TRR. Programmer coding tests have been completed and coding has been placed under configuration control. Changes to coding from this point forward are in accordance with formal change control procedures. Verification testing assures that the coded program meets the objectives delineated in the "code-to" specification. Validation testing assures the coded program is capable of meeting overall system operation requirements. Testing activity, which began with early definition of testing requirements through the Test Plan and the Test Specification, consists of a repetitive process of incremental testing in the following order: (1) perform test procedure; (2) verify test results; (3) retest and make changes if necessary; and (4) write test report. Verification Review (VR) is held at completion of verification, Acceptance Review (AR) at completion of validation. A Systems Review is held after integration tests are complete, and before flight.

7. <u>Use Phase</u> -- Acceptance of the software and its support documentation by the customer opens the use phase, the final phase of the software life cycle. This phase includes any certification testing that requires software support. Maintenance operations are serviced as needed. Responding to new requirements requires that each development step be addressed in a form commensurate with the particular change involved. An abbreviated cycle may be evolved, but all steps must be present in at least rudimentary form.

B. Management Control

Operational software development requires planning and control analogous to the hardware development it supports. Definition,

requirements analysis, design, build and test must be conducted, reviewed and documented in accordance with standards and procedures that are proven effective. The management controls, outline in this section have been selected from practices proven on the Titan, Viking, and Skylab programs, and tailored to meet the special requirements to be encountered on the AMPS program. Particular attention has been given to the fact that AMPS is a software applications program -- one where computers and operating systems from the more general STS and Spacelab programs are married to specific experimenters requirements. Attention is given to meeting constraining interface controls while providing required experiment flexibility.

1. Review/Documentation Plan -- The conceptual phase/review structure to be employed in the AMPS software development will be conducted along the following lines. The first phases (definition, requirements, preliminary design, detailed design and build) are formally reviewed on completion. The test phase is incrementally reviewed at a verification review, a validation review and an acceptance review. Each of these reviews is supported by the appropriate documentation. These reviews are frequent, and will be attended by appropriate management representatives -- assuring timely identification and correction of any development incompatibilities.

Management control documents will be developed for AMPS. A listing of these is provided in Table VI-1. The useful life of each control document may possess four control states. Initially, a draft will exist which is not officially released. This document is the first draft of the Software Development Plan. Then the draft may be released for review, but not maintained. In the early maintenance stages, when the document being controlled is still in a rapid state of evolution, maintenance will be handled by the AMPS prime contractor. When the document is frozen by the customer, all changes will be approved by him. In the case of requirements document, customer control begins before design of the software begins. In the case of design specifications, customer control does not begin until they represent the "as-built" configuration.

2. Configuration and Data Management Plan -- Configuration management of AMPS program software is based on the release and control of documents and software configuration items. The configuration control of software consists of release schedules, change activity and final acceptance of all designated documents and configuration items. These tasks are the responsibility of the Software Control Board (SCB), which is subordinate to the integrating contractors Configuration Control Board (CCB).

The objectives of the SCB are to restrict changes to those necessary to correct deficiences, improve operation and performance, reduce costs and/or improve performance. It is the responsibility of the SCB to review and approve change requests and to coordinate proposed changes with hardware design groups and other affected disciplines. The SCB

Table VI-1 Software Control Documentation

System Level Control

Software Development Plan
Software Test Plans
Computer Resources Integrated Support Plan

Requirements Control

Mission Planning Functional Requirements
Payload Integration/Test/Launch Functional Requirements
Shuttle/AMPS Support Functional Requirements
AMPS Flight Applications Functional Requirements
POCC Functional Requirements

Design Control

Mission Planning Design Specification
Payload Integration/Test/Launch Design Specification
AMPS Flight Applications Design Specification
POCC Design Specification

Test Control

Mission Planning Test Specification
Payload Integration/Test/Launch Test Specification
Shuttle/AMPS Support Test Specification
AMPS Flight Applications Test Specification
POCC Test Specification

Interface Control

AMPS/Spacelab Software ICD
AMPS/Orbiter Software ICD
AMPS/STS Ground Operations Software ICD
AMPS/STS Flight Operations Software ICD

will be composed of a board chairman (who is the software development chief), a board secretary, a change coordinator and representatives from the software development groups, contracts and quality assurance.

Release of documentation and configuration items will be under the control of the SCB, as will the change control of released documentation. The change process flow is shown in Figure VI-1. The process is initiated by any person on the program who recognizes a need. A distinction is made between Class I and Class II changes in the process. Class II changes are defined as those influencing only the internal design of the software -- but having no effect on the requirements to be met by the software, on any external interfaces, or on any documentation that is under customer configuration control. Class I changes are those that do have an impact on these items. Class II changes can be approved for incorporation autonomously by the SCB. Class I changes, on the other hand, must be approved by the higher level CCB process before incorporation.

The details of software related data management are handied under the direction of the SCB. The objectives of this activity are to: (1) identify, justify and acquire the essential data necessary for planning, implementation and control of project activities; (2) establishing requirements for types and quantities of data and schedules for the submittal of data; (3) define content of required data; (4) determine distribution requirements; and (5) monitor documentation schedules and performance. These activities are conducted under the cognizance of the contracts and quality assurance personnel who are members of the SCB.

3. <u>Quality Assurance Activity</u> -- Quality Assurance (QA) will assure that established design, coding, test and use standards are met. When special project-peculiar requirements are incorporated into the Programmer's Handbook, QA will monitor the development activities for compliance.

Program Development and Test Library services are the responsibility of QA together with configuration item designation and control functions. Configuration audits throughout development will be a prime responsibility, as well as required distribution of Computer Program Configuration Item listings and data.

4. <u>Software Use Plan</u> -- Software use encompasses configuration item delivery, major system test support, maintenance and training. The software development task is not complete until the ultimate user is familiar with its capabilities and comfortable with its operation. Even then, a procedure for coping with irregularities encountered during operation is required. The following elements comprise the AMPS Software Use Plan.

a) <u>Delivery</u> -- The step by step computer operations required to output each configuration end item are to ensure that the data on

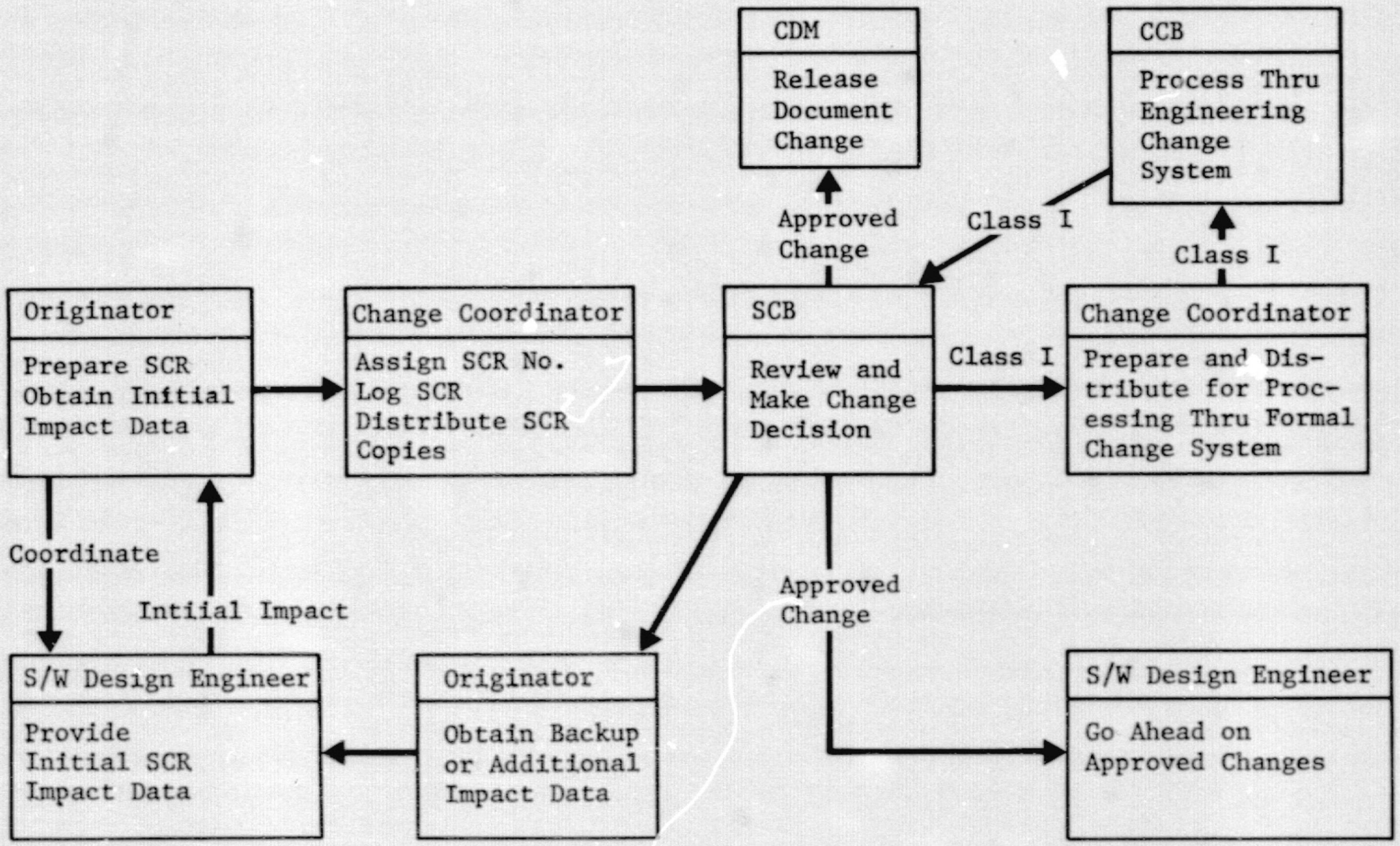


Figure VI-1 Software Change Process Flow

end item is readable by the customer's equipment; to ensure that the storage media contains the proper information to enable performance of the customer's required functions; and to provide adequate end item description, external labeling and internal labeling. The end item deliverables package will include object program medium; data base medium; printed listings or magnetic tape; and memory maps. Physical preparation of the delivery package will include a review to assure that adequate protection is provided against environments/hazards to which the end items will be subjected.

b) Installation -- Mission planning software is installed at the integrating contractor's site in the normal course of development. Orbiter flight software installation is not the responsibility of the AMPS integrating contractor. EGSE software is installed as a part of the Level II integration activity, as is the CDMS flight software. POCC software is installed at the operations center during the same time frame.

c) Operations -- Operational requirements will be detailed in the appropriate users manuals.

d) Maintenance -- Software maintenance shall be accomplished in accordance with the established configuration management procedures.

e) Training -- Training is the process through which the user learns from the developer how to operate the software system. Training considerations are addressed during all phases of program development to assure an orderly transition into the use phase. The fundamental consideration throughout all phases is that all effort be user oriented. Preparation for this training/transition will include a training requirements analysis including consideration of recipients, course work, manuals and sessions; and training program development, including its impact on the design, build and test and use phases of software development. Adequate training is the key to successful operations, and will receive appropriate emphasis.

C. Resource Plan

The principal resources required for software development, other than manpower and the software tools previously discussed, are laboratories and computer hardware. This section presents the AMPS support plan for the prime contractor's laboratories, the general purpose computers, and their required interconnections and interfaces.

1. Prime Contractor's Laboratories -- The prime contractor will provide three laboratories which will be used in the development of AMPS software. These include an AMPS software development laboratory, an Orbiter aft crew station mockup, and a man-computer interaction laboratory. These facilities provide a complete capability of supporting the requirements, design build and verification/validation testing phases of AMPS software development.

The software development laboratory is built around a GFP IBM-370 computer. In conjunction with the support software, it provides a capability to evolve and checkout software intended for use in the Mitra S/MS 125 computers used by Spacelab. More uniquely, this development laboratory provides a capability for the varied instrument/experiment developers to evolve operating sequences/plans that are compatible with the overall AMPS system. Each is provided with a time shared interface which, while it is functioning, is identical to the true Spacelab environment. This approach permits conducting functional system level tests while the participating hardware remains in diverse locations. Further, it permits these developers to gain a thorough familiarity with the Spacelab CDMS without tieing up a Spacelab simulator.

An Orbiter aft crew station mock-up is currently under development at Martin Marietta. This laboratory facility permits the development of the software and procedures that link the activities of the Orbiter aft crewman and the Spacelab crewman. Examples of this coordination requirement include operation of the RMS in support of EMI and wake measurement experiments. Again, the use of this laboratory in the prime contractor's facility eases the scheduling problem of Orbiter simulators at JSC and KSC.

The Man-Computer Interaction Laboratory provides another tool for the development of the AMPS software system. In this case, the interface to be mechanized between the flight crew and the AMPS experiments is at issue. Specific control/display mechanisms can be implemented and evaluated at relatively low expense. For example, the use of particular function keyboard assignments as opposed to an AMPS peculiar operator language will be compared for use in conjunction with specific display formats. This is an important tool in evolving design requirements and the design that implements them.

2. Computation Facilities -- Software development requires the use of a host computer capable of simulating the operation of the Spacelab flight computer, use of the flight computers themselves, and an array of support computers.

The Spacelab host computer is the IBM 370. One of these computers will be placed in the prime contractor's software development facility as government furnished equipment. The software complement (interpretive computer simulator, compiler, linkage editor, etc) required to support this computer is also provided as GFE.

The IBM 370 host computer eliminates the need for a flight-type computer in the prime contractor's software development laboratory. The actual flight computer will be married with the AMPS payload during Level II integration at KSC.

Scientific computer support at the prime contractor's facility will be provided by the currently operational CDC 6000 computer facility. Computational facilities at GSFC (POCC support), JSC (Spacelab Simulator support) and KSC (Level II and III Integration Support) will be provided by the systems that are operational for general program support at the time of AMPS usage. This type of AMPS mission support is not seen as a potential problem area.

VII SYSTEM TEST

This section presents the AMPS system test and verification approach as it was developed during the Phase B study. It will be the basis for the Phase C/D development of the system test and verification program which will demonstrate through test and verification methods that the hardware and software will accomplish their intended functions. The level of detail presented herein is consistent with the definition status of the AMPS system and is sufficient to scope the extent of the overall test and verification program. The facility requirements for the test activities are given in Section X of this document.

Since verification by test is by far the costliest method, the following discussion will generally be limited to test activities. It is assumed that analysis and other assessment methods are used in parallel to support the test activities or are used independently to verify other appropriate characteristics.

A. Guidelines and Criteria

The following guidelines and criteria apply during the identification and implementation of the test and verification program for AMPS:

1) The objective of the program is to demonstrate and document that the flight and ground systems satisfy their specification requirements.

2) The AMPS test program shall be an integrated test program. The test management shall ensure this through the continuity in test activities throughout the buildup of system elements. Inherent in planning of the buildup process shall be the objectives of:

   a) Minimizing test duplication;

   b) Maximization of standard tests;

   c) Combination of tests;

   d) Commonality in utilization of resources;

   e) Testing at highest assembly levels practical;

   f) Uniformity in handling of information (management, technical.

3) Test emphasis (use of actual test methods) shall be applied towards cost effectiveness through the application of cost/value criteria to system elements in relation to their contribution to mission safety and/or objectives.

4) Analytical methods shall be used to support tests or in lieu of tests whenever practical to satisfy verification requirements.

5) The verification program will confirm that hazards identified by FMEA or other analysis have been eliminated by design or reduced to an acceptable level using safety devices, warnings or special procedures.

6) The planning of verification program shall provide for flexibility to accommodate changes necessitated by verification results, program redirection or as a result of continuous evaluation/monitoring of the cost/value effectiveness of verification activities.

7) After each flight, minimum testing will be performed consistent with determining that refurbishment, repairs, and reconfiguration were correct and that the system is ready for reflight. In general, testing for the next flight may be limited to that required to validate refurbishment, repairs, and configuration changes made after the previous flights.

8) The policy regarding test documentation requirements at various management levels shall be flexible with the objective of minimizing the variety, quality and formality of the documentation required.

B. Requirements

The AMPS payload and its elements are subject for compliance with two sets of verification requirements. They are those imposed on users by Spacelab and STS projects, and those established by AMPS project for payload elements under its control. The first generally concerns itself with the verification of interface compatibility; whereas, the latter defines detail requirements for the verification of design and performance requirements of the payload elements.

The external requirements originate from JSC-07700, Volume XIV - Space Shuttle System Payload Accommodations; the Spacelab Payload Accommodations Handbook; and K-STSM-14.1 - KSC Launch Site Accommodations Handbook for STS Payloads.

These documents impose design and performance requirements on the AMPS payload and, therefore, also impose verification requirements. In the course of the AMPS program, these requirements must be identified, their implementation planned and coordinated and, finally, implemented. Space Shuttle System Payload Interface Verification Plan (JSC-07700-14-PIV-01) defines this process for the STS/payload interfaces.

The AMPS internal verification requirements will be defined in GSFC General Environmental Test Specification for Space Shuttle Payloads (to

be prepared). This general specification, in conjunction with project directives and policies, will be used to define specific verification programs for individual payload elements.

Another set of verification requirements within the STS, Spacelab and AMPS relationship are the requirements imposed by AMPS on the other projects. Typically, these requirements will entail the verification of interface status prior to mating, functions across interfaces and the required participation in STS verification activities.

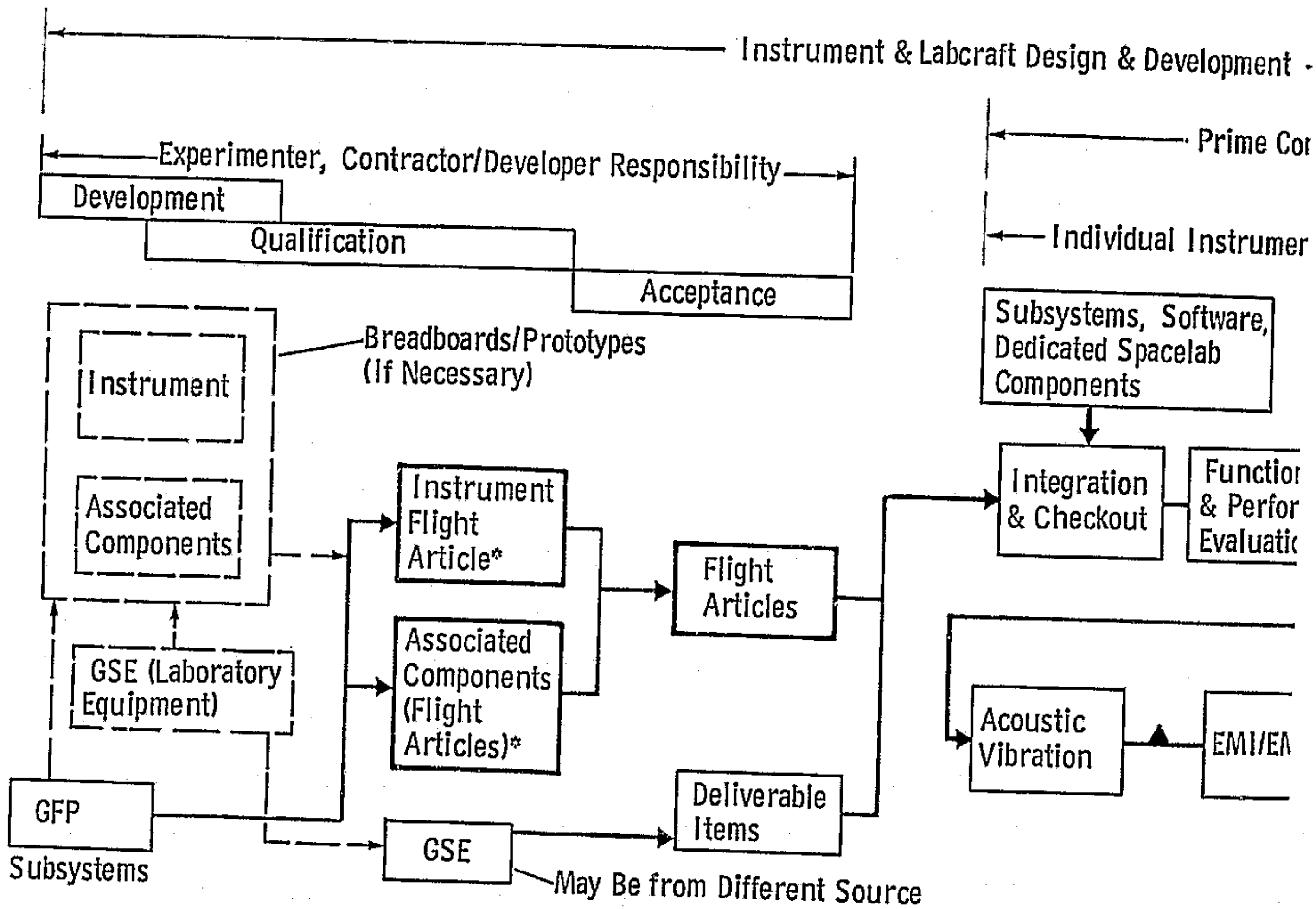
C. Verification Approach

The verification approach presented herein is the baseline approach that was identified during the course of the Phase B study. It is based on the protoflight hardware build and test concept used successfully by GSFC, is compatible with STS philosophy and follows the guidelines and criteria stated previously. In essence, the approach does not deviate substantially from the past approaches used for spacecraft type programs.

Figure VII-1 is the AMPS payload verification flow. It has two major parts; namely, instrument and Labcraft design and development and complete payload integration and checkout. The two are joined through a milestone designating flight certified status of all equipment entering the integration cycle. For discussion purposes, the instrument and Labcraft design and development is further subdivided into component verification and individual system certification.

1. Component Verification -- The verification flow during the instrument and Labcraft component design and development is shown on the left side of Figure VII-1. It is generalized to accommodate the verification requirements of components diverse in nature and development status. The term "component", as used herein, encompasses items better known as "black boxes" and also subsystems. The flow is the same for instrument and Labcraft type equipment, therefore, unless distinction is made, the following discussion pertains to both types.

The center of the figure in heavy outline emphasizes the protoflight build and test concept. The thrust of the concept is to build, test, refurbish and fly the same article. The components, therefore, will undergo a series of classical qualification tests to ensure reasonable success during system level testing and successful flight(s). The design of such a qualification test program must balance many factors to achieve satisfactory level of confidence, yet not to overtest the articles. As indicated in the figure, project management must weigh the overall test exposure and such factors as cost, design features and associated history, mission objectives, operational mode and environments. Modifications after test failures and refurbishment after test completion, if necessary, will be part of the plans.



*Scope of qualification tests determined by: Project management
Development, acceptance, and system tests
Required deltas

▲ Denotes Functional Te

FOLDOUT FRAME

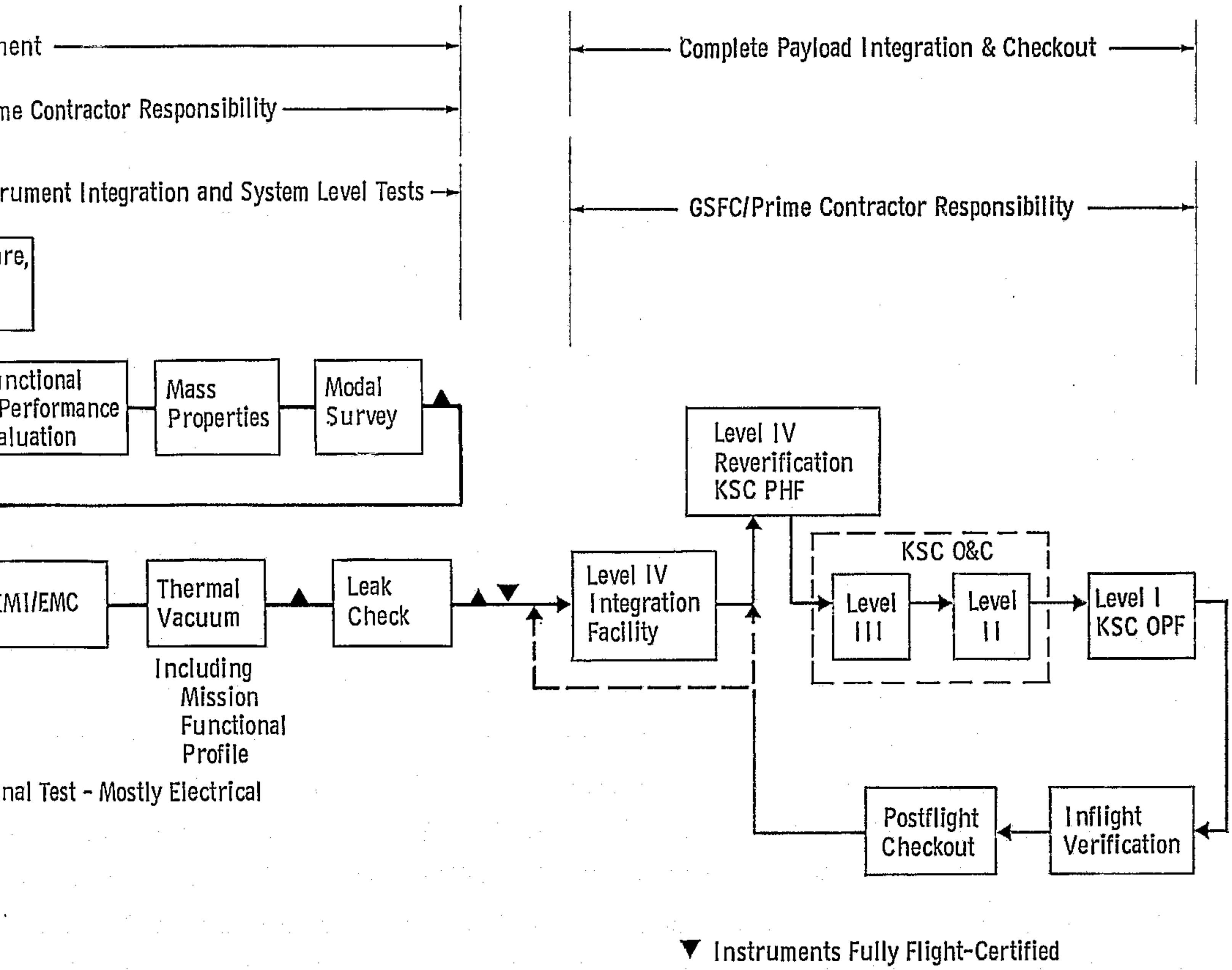


Figure VII-1 AMPS Payload Verification Flow

The figure also shows a longer development path for items requiring additional development testing prior to the protoflight article build. These tests will use breadboard/brassboard/prototype articles in a laboratory environment. Test configurations will include off-the-shelf standardized hardware as well as laboratory type support equipment. Successful tests during this phase will allow decrease in the qualification testing. It is expected that most of the Labcraft equipment will go through the prototype stage of development and testing. These equipment will typically be built more than one in number and their use by instruments require valid performance and reliability baselines.

Acceptance tests at component levels will be used either for quality/workmanship screening, establishing of functional baselines before qualification tests, after refurbishment and prior to integration in higher level assembly. The exact use of acceptance tests for any one item allows much latitude in selection of applicability and use of environments.

Figures VII-2, VII-3 and VII-4 are sample test and verification approaches for three types of AMPS hardware. They were developed within the context of the overall approach described herein using the available design information. Figure VII-2 shows the required tests for the Laser Sounder instrument. For this instrument, most assemblies begin with the protoflight article, however, because at extensive development needs, the Light Source assembly will go through breadboard and prototype stages. Figure VII-3 shows the Spectrometer Array test program. It is typical for off-the-shelf variety equipment. Figure VII-4 shows the approach for a production type flight safety critical mechanism. This items requires a prototype and a qualification unit. The latter may become a flight unit after refurbishment, if the conditions so warrant.

Following component level tests, the components will be integrated in their respective higher level assemblies for system level tests and certification. This phase of testing is discussed next.

2. <u>Individual System Certification</u> -- The instrument level test flow is shown in the center of Figure VII-1. Typically this is a higher level of assembly which includes the components discussed in the preceding paragraph, standardized hardware, support equipment and software. The assemblies will represent a functional instrument entity. This assembly and test phase for the various instruments will be the responsibility of the prime contractor and will take place at his facility. The objectives of this activity are to integrate the instrument functional elements and to subject the flight system to a series of environmental and special tests. These tests, along with the other previous verification activities designated as requirements for certification will complete the certification cycle.

Figure VII-1 shows a typical series of tests which may or may not be required for all instruments. Here again, the project management must choose the applicable tests in light of similar factors as those for

Tests / Level of Assembly	Development														Qualification 1 Unit°						Acceptance			Systems (Protoflight)						
	Breadboard					Prototype (1 Unit)																								
	Functional Performance	Sensitivity & Tolerances	Calibration	Interfaces	EMI/EMC	Functional Performance	Interfaces	Parametric Voltage	EMI/EMC	Calibration	Weight & cg	Vibration	Leakage	Thermal Vacuum	Functional Performance	Weight & cg	Vibration	Leakage	EMI/EMC	Thermal Vacuum	Functional Performance	Vibration	Thermal Cycling	Functional Performance	Weight & cg	Modal Survey	Acoustic Vibration	EMI/EMC	Thermal Vacuum	Leak Check
Transmitter (1 of 2)																														
Transmitting Optics Assembly															X	X	X	X		X	X									
Laser Light Source Assembly	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									
Electronics Assembly															X	X	X	X	X	X	X									
Complete System																								X	X	X	X	X	X	X
Receiver																														
Collecting Optics Assembly															X	X	X			X	X									
Detector, Filter Assembly															X	X	X	X	X	X	X									
Electronics Assembly															X	X	X	X	X	X	X									
Complete System																								X	X	X	X	X	X	X

° To be refurbished (If required) for protoflight article.

Figure VII-2 Laser Sounder Verification Approach

Level of Assembly \ Tests	Qualification						Acceptance			Systems*						
	Functional Performance	Weight and cg	Vibration	Leakage	EMI/EMC	Thermal Vacuum	Functional Performance	Vibration	Alignment	Functional Performance	Weight and cg	Modal Survey	Acoustic Vibration	EMI/EMC	Thermal Vacuum	Leak Check
Spectrometer Array Package	X	X					X	X	X	X	X	X	X	X	X	X

* Combined with canister and gimbal.

Figure VII-3 Spectrometer Array Verification Approach

Level of Assembly \ Tests	Development (Prototype - 1 Unit)											Qualification (1 Unit)						Acceptance (All Units)			
	Functional Performance	Tolerances (Voltage, Noise,	Mechanical, ΔV)	Weight and cg	Vibration/Acoustics/Modal Survey	Pyro Shock	EMI/EMC	Leakage	Thermal Vacuum	Failure Modes		Functional Performance	Weight and cg	Vibration/Acoustics	Thermal Vacuum	EMI/EMC		Workmanship	Functional Performance	Random Vibration	
Gas Storage/ Activation Assembly	X	X			X	X												X		X	
Cylinder and Holddown Assembly	X	X																X			
Complete Assembly	X			X	X	X	X	X	X	X		X	X	X	X	X		X	X		

Figure VII-4 Cold Gas Ejection Subsystem Verification Approach

component qualification tests. Additions or modifications may be necessary for some instruments; i.e., added magnetics evaluation as conduct of a thermal test in lieu of thermal vacuum.

The test phase will start with integration and functional checkout followed by functional and performance evaluation. The latter will include system parametrics as well as the evaluation of system sensitivities. The results will serve as a functional baseline for determination of effects from subsequent environmental exposures. After final test, the instrument will be subjected to a thorough functional test in preparation for shipment to the integration site.

3. <u>Complete Payload Integration and Checkout</u> -- Following the instrument system level tests, the AMPS payload elements will begin the complete payload integration cycle. It will take place in several levels progressing from instrument, Labcraft and pallet integration (Level IV) to Spacelab/AMPS payload and Orbiter (Level I). The successive levels emphasize the integration and checkout of new interfaces associated with the new level of integration.

a. <u>Level IV Integration</u> -- The objective of Level IV integration is the integration and checkout of the individual instruments, pallets, racks, GSE, Labcraft, simulations and the complete AMPS payload (soft-mated). It is to be performed at the prime contractor's site. Since it is the first and lowest level of integration, it will be more detailed and extensive in scope. Consequently, from verification point-of-view, it will satisfy many requirements.

Figure VII-5 is a functional flow of Level IV integration for the first AMPS payload. It shows a gradual buildup at individual instrument level leading to complete payload configuration integration and checkout. Besides functional verification, it will also include first time evaluation of EMI/EMC at the complete payload level. As indicated in the figure, the flow will be significantly reduced for follow-on flights with the elimination of pallet level tests (acoustic vibration and modal survey). It is considered necessary to perform these tests on first set of pallets to acquire data for confirmation of analysis and modeling results. The tests will be performed with a single pallet at a time in a facility other than the clean room used for integration and checkout. To accomplish this, the pallets will be demated after complete payload tests and returned to the same configuration and functional status afterwards. Next, the pallets will be demated, prepared and shipped to KSC.

The assumption regarding the pallet level tests is that the entire payload complement, i.e., instruments, Labcraft are to be flown for the first time. If, however, a significant number of

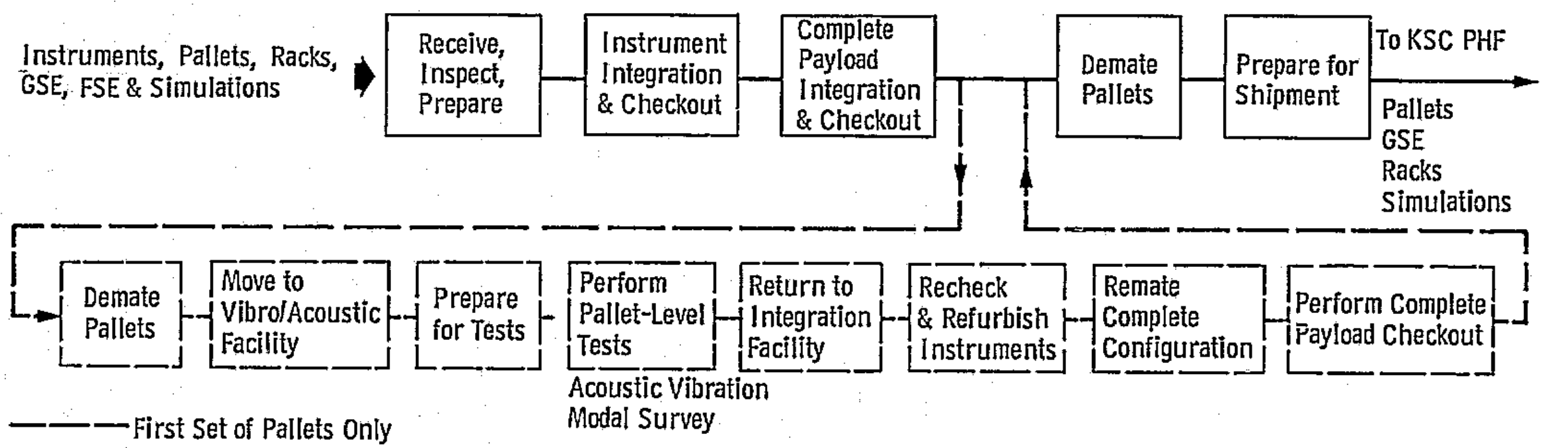


Figure VII-5 Level IV Integration Functional Flow

Labcraft or instruments will have been flown previously, the necessity for all or part of the pallet level tests should be reconsidered. Another factor to enter this decision will be the availability of applicable data from previous Spacelab flights, i.e., orbital test flights.

Figure VII-6 is included to show the functional configuration of Level IV integration. It shows the instruments on a pallet interfacing with the data bus and their own unique GSE. This dual interface is desirable for gradual integration, troubleshooting, and the evaluation of science data interface not accessible through the data bus. The computational equipment in combination with the peripherals will perform the functions and simulations of the Spacelab and Orbiter systems not part of this configuration. Software used by this equipment will be as far as possible Spacelab and instrument flight software modified for ground use. Simulations will be substituted for the missing functions and interfaces.

After the completion of Level IV integration at the prime contractor's site, the pallets will be demated and transported to KSC Payload Handling Facility (off-site).

b. Level IV Reverification -- The objective of reverification of Level IV configuration at KSC is to reconfirm functional status of the payload which might have been altered due to the elapsed time and the effects of transportation. It is also likely that som. changes may be necessary prior to the commitment for further integration. To achieve this, the pallets will be remated (soft) and, using the same support equipment configuration shown in Figure VII-6, brought up to the final complete payload functional status which existed at Level IV integration.

It should be noted that this reverification activity will be the last phase under payload development center control. Therefore, it is the final opportunity to perform certain types of final checkout which may be time consuming or may require special conditions or equipment.

From PHF, the payload pallets will be transported for Level III/II integration and checkout in the Operations and Checkout Facility.

c. Level III/II Integration -- The objective of Level III/II integration is the integration and checkout of pallet, train, racks, Spacelab and the complete Spacelab and AMPS configuration. The Spacelab and payload will be assembled in the integration and checkout stand and mated to support equipment. Figure VII-7 shows the functional configuration of the airborne and ground equipment. New in this configuration as compared to Level IV integration is the actual Spacelab Core Segment with its Automatic Test Equipment (ATE)

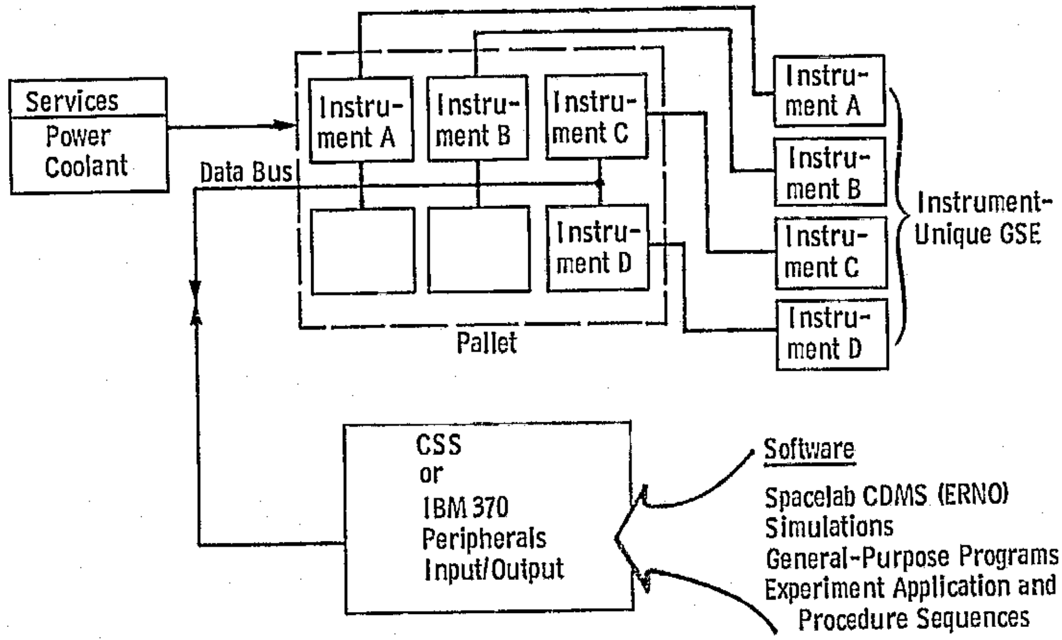


Figure VII-6 Level IV Integration Configuration

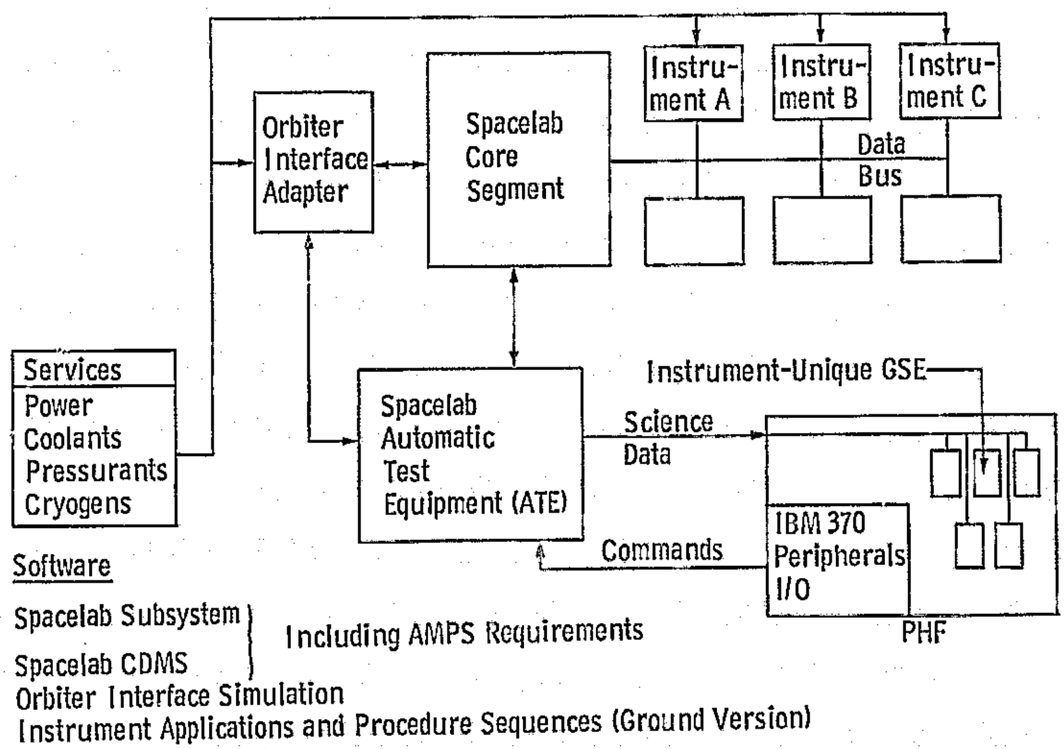


Figure VII-7 Level III/II Integration Configuration

and Orbiter Interface Adapter (OIA). Also shown is a tie-in of previous configuration support equipment, located at the PHF, with the payload via the ATE. The instrument unique GSE located at the PHF can only receive science data demultiplexed by the ATE while other support equipment can command the instruments.

This activity will see the hard mate of pallets, installation of racks and step-by-step integration and checkout of the Spacelab with the payload. The features and functions to be verified include physical accommodations, utility services, command and data management and software. After the confirmation of overall functional compatibility, several system level tests will be performed. These are mission simulation, EMI/EMC, determination of science data rate capabilities and data interface with MCC. Weight and c.g. determinations will be made as part of handling of the Spacelab and payload assembly for transferring to Orbiter Processing Facility which is the location for Level I integration.

d. Level I Integration -- The objective of Level I integration is the integration and checkout of the remaining new interfaces. They are:

1) Spacelab to Orbiter physical interfaces (fit, clearances) and functional interfaces (power, coolant, command and data, caution and warning and Launch Processing System).

2) Tunnel installation involving fit and leak tests.

3) Payload Specialist Panel installation involving physical fit and functional tests.

Following the verification of individual interfaces, integrated system checkout of the Orbiter/Spacelab interfaces will be performed as part of Orbiter Integrated Test. During this test, AMPS participation will be in a passive support role of providing the required functions and responses. AMPS payload will play a similar role during the rollout, final checkout at the pad and launch.

VIII MANUFACTURING

This section defines the manufacturing and tooling tasks and activities associated with the implementation of the AMPS Phase C/D effort. It presents the approach for accomplishing each manufacturing and tooling task for the flight hardware, the AMPS/Labcraft assembly GSE/STE, the development and test hardware, spares and that equipment which requires refurbishment. It also includes a brief description of the manufacturing organization and some of the manufacturing controls that would be used.

A. Flight Support Equipment Fabrication and Assembly

Manufacturing planners and producibility specialists initiate interaction with the FSE design team during the initial Phase C start-up efforts so that the PDR configuration will reflect these manufacturing inputs. Efforts will be amplified during the major design period between PDR and CDR to assure that the lowest cost techniques and designs are specified and are compatible with existing manufacturing capabilities.

Manufacturing details will be fabricated primarily in the first floor main factory area. Electrical details will be fabricated in the Electronics Manufacturing facility. Both approaches will use AMPS project approved techniques that are based on existing Shuttle hardware fabrication practices.

All manufacturing details, together with instruments, pointing platforms and other GFE, will be delivered to the AMPS dedicated assembly area located in a specially partitioned section of the Space Support Building (SSB) high bay area where a sequential buildup of components and assemblies is completed and the mating and checkout of both Martin Marietta and GFE assemblies is accomplished during the Level IV integration activities.

The AMPS modular design approach supports an efficient fabrication approach and makes maximum use of subassembly techniques. Concurrent assembly of individual pallets and attached hardware is feasible with separate assembly of the individual deployed modules on individual workstands. Thus the ESP module, the beam diagnostic package, the six chemical release modules and the RF receiver package can be individually assembled, tested and checked out to make best usage of the spacecraft assembly technician without impacting major pallet installations and assuring fabrication in a minimum span time.

Structural trusses and brackets will be fabricated and assembled in the factory under conventional shop temperature, humidity and cleanliness conditions. Mechanical deployment devices will be similarly fabricated but final assembly will be made within class 100,000 clean rooms in the adjacent factory area. Electrical/electronic components and assembly will be performed in the class 100,000 clean rooms of the

Electronic Manufacturing Facility. Power supplies and batteries will be assembled and tested in the special battery laboratory. Antennas will be tested at the antenna range. Thermal blankets and cable harnesses will be fabricated in the class 100,000 second floor area of the SSB. Because both blankets and harnesses are development items they will use the full scale mockup to assure precise fitting on the flight pallets.

Mating of the FSE components into subassemblies and installation onto the pallets or into the GFE pointing platforms will take place in a class 10,000 clean Level IV final assembly area of the SSB in order to maintain the cleanliness levels required by the AMPS instruments (as specified in the AMPS contamination control plan) and to meet applicable NASA external cleanliness levels.

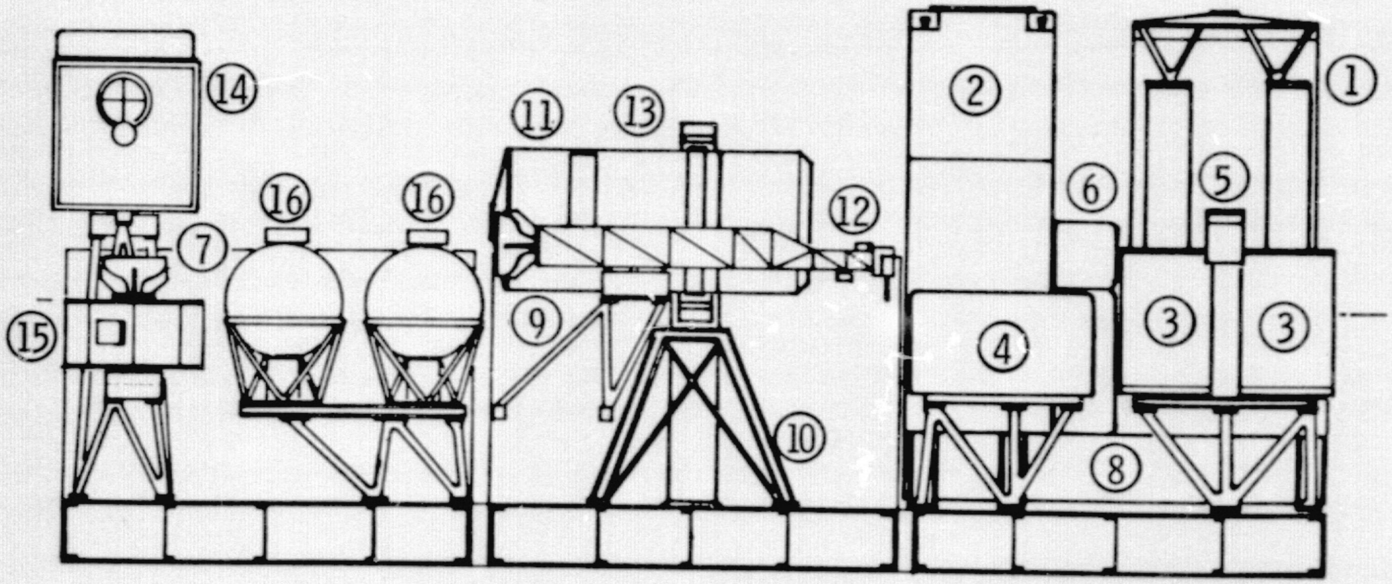
Fabrication of the supporting structures and mechanisms is within the existing technology, skill experience, available equipment and facility capabilities at Martin Marietta. Soft tooling fixtures, suitable for the low production rates, and using a rigid support base with accurately dimensioned pallet interfaces and reference surfaces, will be used to control the geometry of the assembled structures. The fixtures will also be used to support sections for equipment installation and assembly. Drilling of precision hole patterns will be accomplished with standard jig boring and vernier positioning equipment.

FSE detail parts will be fabricated primarily using standard techniques and tooling. Milling, drilling, boring and turning operations for the low quantity elements for frames, brackets, boxes and fittings will not require special holding fixtures. Shop type mylar templates will be used for fabrication of the multilayer thermal blankets and tailored to fit the individual pallets. Electrical wiring will be initially developed on the mockup and fit checked on the final flight pallets to eliminate the need for special development tools.

1. <u>Structural Assemblies</u> -- Welded tubular structure with machined interface mounting plates for instruments, FSE and ERNO specified pallet hard point ball assemblies constitute the major mounting method for all payload experimental equipment except the electron accelerator and Lidar telescope which use the pulse power structure.

Figure VIII-1 identifies the welded tubular structures on flight 1, which includes the following distribution of items on the various pallets:

a) Forward pallet: ESP mounting truss; minimount mounting truss; near-IR launch/landing support truss; gas release primary truss; six gas release secondary trusses; and the ESP structure.



Side View

Legend:

1. Lidar Receiver
2. Electron Accelerator
3. Lidar Transmitter
4. IECM
5. Solar Flux Monitor
6. OBIPS
7. Minipointing Mount
8. High-Voltage Power Supply
9. Cryo Limb Scanner
10. SIPS
11. Cryo IR Interferometer Spectrometer
12. Beam Diagnostics Package
13. RF Terminal
14. Near-IR Spectrometer in Environmental Canister
15. Environmental Sensing Package
16. Gas Release

Figure VIII-1 AMPS Flight 1 Structure Requirements

b) Center pallet: RF terminal support truss; beam diagnostic support truss; and beam diagnostics structure.

c) Aft pallet: Minimount mounting truss; OBIPS launch/landing support truss; IECM support truss; Lidar transmitter mounting truss; and solar flux monitor mounting bracket.

Fittings, mounting plates and brackets will be conventionally milled, with numerical control machining on multiple part usage such as ball joint fixtures. Tooling will be machined and welded in soft tooling assembly fixtures. Instrument mounting plates will be drilled using instrument manufacturers' provided templates. All fabrication and assembly will be in the horizontal position with reference to the pallets in the orbiter after landing. Trusses will be chemically cleaned and receive an anodized coating in the Martin Marietta first floor factory chemical plating area. The individual structures are then cleaned and encapsulated in polyethylene wrap and transported to the SSB final assembly area.

2. Mechanisms -- The major frame and baseplate structures are milled using conventional techniques. The internal operating mechanical parts, including stabilizing rods, cam links, attachment hooks, shafts, detents and brackets, are also machined conventionally and combined with procured worm/wheel gearings, bearings and fasteners into mechanical subassemblies. A sample mechanism is depicted in Figure VIII-2. Ordnance operated devices are assembled but will be shipped to KSC separately.

3. Pressure Vessels -- The gas release modules include the large aluminum pressure vessels that have been premachined and tested at the supplier facility so that further machining at the Martin Marietta facility is not required. Similarly, the small prepressurized ejection bottles are received without additional machining required. Support equipment boxes and attach fittings are machined conventionally, with numerical tooling set-ups used where quantities warrant.

4. Thermal Control Hardware -- Multilayer insulation for AMPS will be fabricated in a class 100,000 clean area of the SSB. Insulation materials will be received from the supplier at a cleanliness level 300 and a non-volatile residue level "A" as specified in NASA specification SN-C-0005. The quilted blankets will be assembled in a horizontal laminar flow area. Material trimming and other high rate particle shedding operations will be performed farthest from the air supply filter bank. Final clean and check operations will be completed close to the class 100 incoming air supply. The blankets will be made clean and kept clean. Mylar template patterns for the blanket configurations will be developed on the mockup, checked on the flight vehicle surface and used to control the geometry of each blanket assembly. Figure VIII-3 depicts these blankets installed on the pallets.

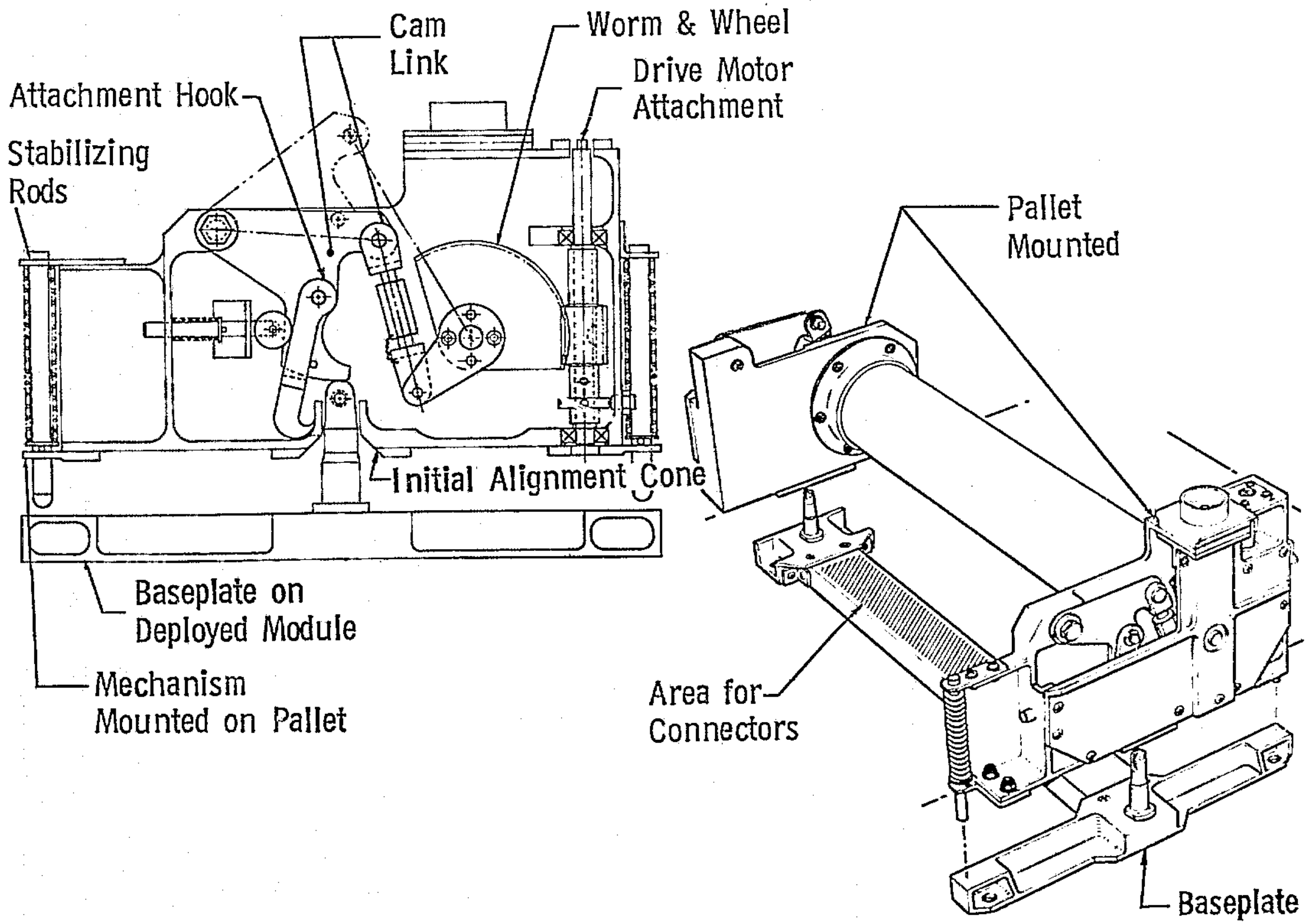


Figure VIII-2 AMPS Mechanism -- Capture/Release Device

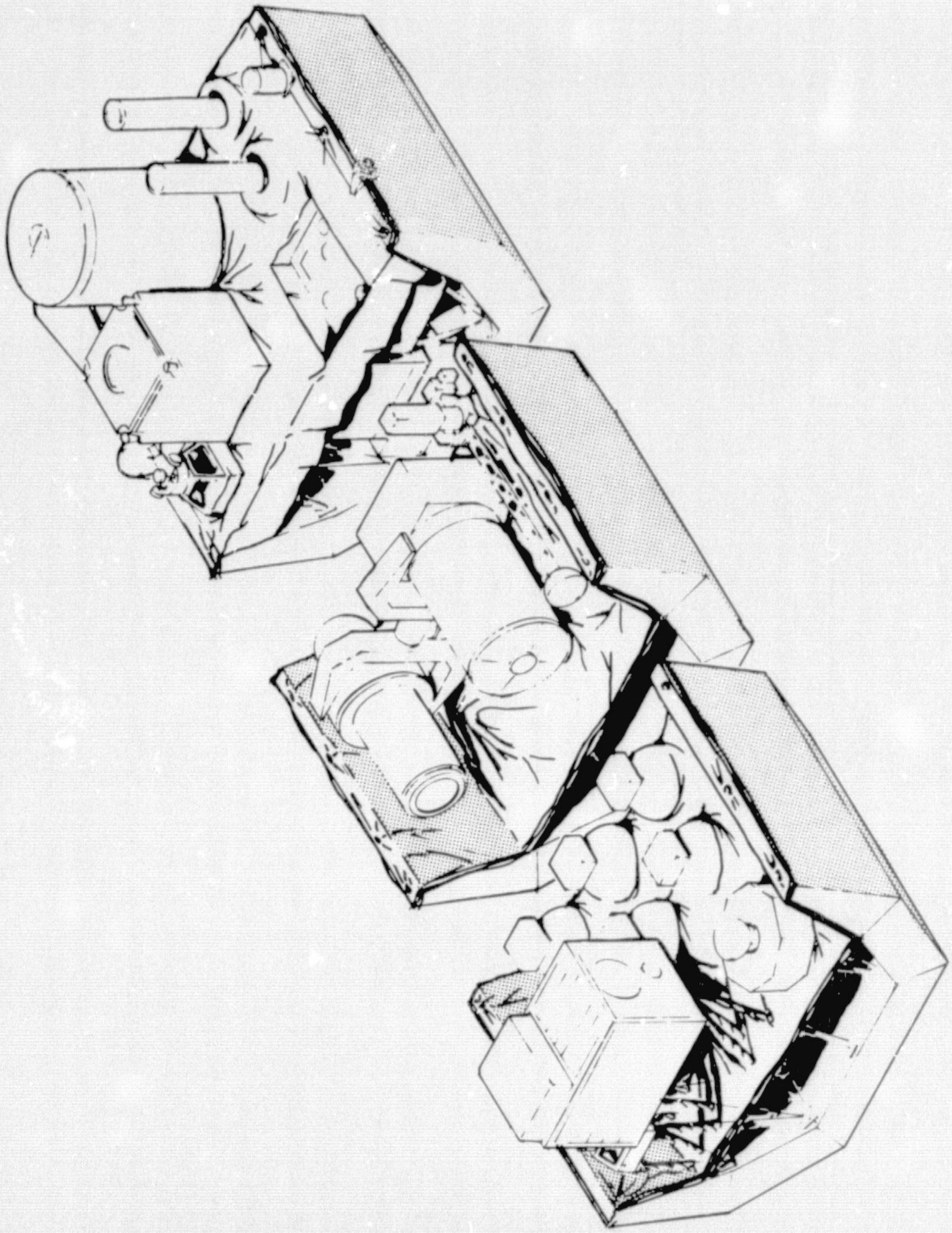


Figure VIII-3 AMPS Thermal Blankets

The silver coated teflon thermal covers will be bonded to the exterior surfaces specified for the ESP. The rivited skin panels will be solvent wiped and oven dried prior to bonding. After the film adhesive is applied, an elevated temperature cure under reduced pressure is required to remove volatiles and accelerate the cure.

Thermal coatings for interior and exterior surfaces of the several deployable modules will be applied prior to system installation and assembly.

5. Electrical/Electronic Hardware -- Several dedicated program areas will support the electrical/electronic fabrication and test. Detail parts fabricated in the detail shop, purchased piece parts and PC boards from subcontractors will be staged in the controlled AMPS area of our Electronics Manufacturing building. All subassembly and assembly of electrical and electronic flight hardware will be performed in class 100,000 clean work areas. Certification logs will be used to control and record the build-up, test and acceptance of all components.

The component assemblies for the electrical power, data management, instrumentation and communication subsystems will be assembled in a dedicated AMPS area of the Electronics Manufacturing facility and the Antenna Test Range. Inductors and transformers will be fabricated and tested. Purchased resistors, capacitors, integrated circuits, diodes and transistors will be screened for high reliability. The piece parts will be installed on printed circuit boards, circuits will be tested and trimmed and the boards will be conformal coated. The completed boards, piece parts, wiring and connectors will be assembled into the structural case. Functional testing will be performed at each level of subassembly. The special equipment and skills for element brazing, welding, soldering, potting, encapsulating, functional test, vibration test and thermal cycling are all available within the Electronic Manufacturing facility.

Vehicle wiring will be developed on the full scale mockup and checked on the flight pallet structures. Development will be performed in the class 100,000 clean assembly area in the SSB. The harness will be removed from the mockup structure to complete potting, tying and cleaning. After thermal coats have been applied to the structures, the harness will be reinstalled and the continuity and megger tests will be performed.

Although current planning is to procure all flight qualified batteries, in the event a make-buy change is made in this area, then the assembly and test of batteries will be accomplished in the battery laboratory. The machined plates, spacers, skins, retainers and connector bracket will be fabricated with existing standard equipment and tools. Proven processes are available for battery fabrication and test. Purchased Ag-Zn cells will be acceptance tested and matched. The battery laboratory existing computer and software will be used to

control and monitor the charge/discharge cycles required to obtain the data for cell matching. The laboratory environmental chambers will provide thermal control of the cells during testing. Battery assembly, cycle test, thermal test, vibration test and final acceptance test will all be completed in the laboratory.

B. GSE/STE Fabrication and Verification

Mechanical and structural system STE will be fabricated, assembled and tested in the same shops as the AMPS flight hardware. Fabrication of the mechanical GSE will be subcontracted. The capability of handling, support and storage equipment manufacturers will be used to build the structural and mechanical GSE. We will, however, perform the load testing and fit check.

The STE electrical checkout and test support GSE which comprises the Level IV Integration Functional Test Set will be fabricated, assembled and tested in the engineering electronics laboratory concurrent with the flight equipment development.

All GSE will be fabricated and assembled in conventional factory environments. The external surfaces of the equipment will be cleaned after assembly to upgrade it for required clean room compatibility. Certification logs will be used to control and record assembly and test of all GSE/STE components.

C. Development Hardware Fabrication

Development test hardware for the gas release, capture release and deployment mechanisms will be fabricated and tested in the same manufacturing facilities that will produce the flight articles. Special processes and tools will be proven on the development articles to assure their availability for flight article fabrication.

D. Spares Fabrication and Refurbishment of FSE

Fabrication of FSE spares will be performed by the manufacturing parsonnel that fabricate the flight hardware. Refurbishment and retest of the qualification test article mechanisms and electronic components identified for flight spares will be accomplished in the same time frame as build of the flight hardware. The necessary details to support the refurbishment will be fabricated with the flight article details using the same processes, techniques and tooling.

The AMPS FSE refurbishment capability will be included in fabrication plans and tools. Build plan records will be documented with sufficient detail to assure a duplicating capability for hardware fabrication. Tooling will be designed to include downstream usage.

E. Organization and Responsibilities

Manufacturing management, planning and supervision will be on-board the program team at the beginning of Phase C/D. This nucleus will physically move with the design, fabrication, assembly and integration activity. Simplified process and fabrication instructions will be prepared on project. Task managers will provide on-site coordination to all program fabrication areas. On-site liaison coverage with advanced design change notices (ADCN) issued as the authority to proceed with changes will also be provided. Detail fabrication and component assembly is planned with standard tooling and multiple function tooling with most detail tools being built on project. All material and hardware movement will be controlled by manual statusing.

1. Dedicated Shop Operation -- Selected shops within existing manufacturing facilities will be assigned as dedicated areas for fabrication, assembly and test tasks. Subsystem fabrication in the dedicated areas will be directed and controlled by the appropriate subsystem manufacturing manager with close coordination with the engineering task manager. The manager will provide direction to area supervisors for all fabrication activity. The fabrication supervisors will be responsible for area operation. The supervisors will have been program team members since the onset of the design phase with the responsibility for coordination of the requirements, material, tooling and the fabrication plan.

The dedicated shops will use experienced personnel in the use of summary or single step shop traveler plans, shop-aid/non-design tooling and end item inspection. Those detail fabrication items that require specialized equipment or large capacity equipment will be processed through the production shops or subcontract shops to use their existing special abilities.

2. Production and Material Support -- Production and material support team members will direct and regulate the orderly flow of hardware through the fabrication, test, checkout and delivery cycles. During the engineering design, development and release they will establish material and parts requirements. Industry suppliers will be screened to establish sources for AMPS materials, parts, components and support operations. They will prepare a plan to status and control materials, shelf item components, vendor components, in-process hardware, tools and shop loads. They will be responsible for developing, issuing and maintaining page and line schedules for all manufacturing tasks. The page and line schedules will provide the basis for identifying long lead activities.

Production support will be responsible for the movement and staging of materials, tools and components. They will control pack and ship operations for in-process hardware and program end items.

F. Manufacturing Controls

Manufacturing controls which we have used and refined successfully through our past experience and activities as a manufacturing facility will be implemented during the manufacturing phase of the AMPS Phase C/D activity to ensure control of the manufacturing effort and assure producing the required hardware in the most economical and efficient manner. These controls include cost, production, material control and so on as described in the subsequent paragraphs.

1. Cost Control -- A manual and mechanized data collection system will be used to compile labor costs and to provide job status, shop load data and machine operations scheduling. The production activities performed in dedicated shops with simplified process and fabrication instructions and reduced supporting functions will require only that portion of the mechanized system capability that is necessary to assure the ability to maintain positive control of fabrication costs.

Cost data will be collected daily, accumulated and reported to program management. The data will be provided by functional element and manufacturing control points which relate directly to the Work Breakdown Structure (WBS) elements.

Project directives will be issued to authorize and direct manpower and material expenditures for specific tasks. The project industrial engineer will initiate and control the collection of costs that must be analyzed with the budgeted elements. He will prepare timely reports for the appropriate subsystem managers. The reports will provide actual labor and material costs to the WBS unit for the current reporting period and program accumulation.

2. Production Control -- Production control support will consist of three basic elements: Project Production Control; Integrated Planning and Scheduling; and Shop Control.

Project Production Control will be responsible to the assembly and check-out lead for all manufacturing planning and status. Integrated Planning and Scheduling will develop the detailed manufacturing schedules for assuring effective use of manufacturing resources since AMPS fabrication effort must be integrated with other on-going programs. Shop Control, using the page and line schedule and indentured parts list, will be responsible for the control, movement and status of all raw material, procured items, vendor components, shop folders, certification logs, tools and shop loads.

Program directives will direct all manufacturing functional elements, define the tasks and establish quantity requirements, schedules and cost accounts for labor and material. Production control will identify and initiate all parts requirements in accordance with engineering drawings. They will participate in configuration control, direct change activity within manufacturing and will control pack and ship operations.

Production control manual and computerized systems will be the tools for program management to maintain visibility of performance to build status, schedule and cost. Progress reviews at the working level will provide timely recognition and resolution of problems when they occur and in time to reduce any detrimental impact.

3. Manufacturing Engineering -- Preproduction engineers will be collocated with engineering during the complete design phase. The manufacturing engineer will review design concepts to assure the interchange of producibility and design requirements. He will develop the fabrication plan, analyze alternative approaches and minimize technical and production risk. Manufacturing data establishing the fabrication plan, techniques, tooling, manufacturing processes and special considerations will be issued by the preproduction engineer and released with the engineering design.

The preproduction engineer will assist in the selection of components, parts and operations to be subcontracted in order to use available equipment, processes, techniques and experience to achieve the lowest total cost. Manufacturing engineers will review all engineering releases. They will assure producibility and completeness of manufacturing information (material, processes and techniques) to achieve the lowest total cost. Manufacturing engineers will also be responsible for the technical interface between designers and fabricators during the hardware build phase.

4. Fabrication Process Control -- All processes and technology required for producing the AMPS hardware are within the state of the art. Manufacturing processes will therefore be adapted to AMPS from existing NASA and industry technology. Adapted processes will be reviewed by experienced laboratory technicians and manufacturing specialists and approved by Quality, Safety, Manufacturing and Materials Engineering personnel before release for production. Potential problems or concerns with existing processes which may necessitate modification for use on AMPS will be identified and the planned approach for adaptation will be described.

5. Material Control -- Material control will be responsible for the preparation and issuance of all purchase requisitions and will maintain the status of all procured materials and parts. They will review engineering for material and procured parts requirements and establish availability data. They will consult with the design engineer on substitute materials and parts based on stock availability or off-the-shelf procurement. Material control is the single point contact for all program matters concerning material and procured parts.

IX PRODUCT ASSURANCE

A product assurance program will be implemented for the AMPS Payload which provides the highest reliability and availability for the AMPS hardware at the lowest cost. This program will provide the necessary controls to assure that all hardware and software meets engineering and contract specifications. This program is based on the reliability, maintainability, quality assurance and safety requirements established during Phase B and will satisfy the intent of NHB5300.4 (1D-1).

The objectives of these tasks are; to establish and maintain reliability and maintainability requirements for the AMPS payload; conduct reliability and maintainability analyses for the AMPS payload and the support systems; define quality assurance requirements for the AMPS payload; implement a quality program for the AMPS Support Systems; and establish and maintain a safety program for AMPS.

A. Reliability and Maintainability

The reliability and maintainability program will provide for systematic identification and resolution of a potential critical failure. This program will be closely coordinated with the systems safety program and will provide the basis for the safety hazards analyses.

Implementation of the AMPS reliability/maintainability program will be the direct responsibility of the Product Assurance Manager, who reports to the AMPS Program Director. This organization permits Reliability the necessary authority to effectively discharge its responsibilities and provides direct unimpeded access to top management.

We will prepare and submit for NASA-GSFC approval a detailed Reliability Program Plan based on NHB 5300.4 (1D-1). This plan will describe how we will conduct the AMPS Reliability/Maintainability Program and detail procedures for implementing each element of the program. This plan will be available for Phase C/D negotiations and inclusion in the contract and will be updated as required in the contract.

Reliability/Maintainability program control will be assured by the implementation and completion of the reliability/maintainability tasks in a timely manner.

Subcontractor/supplier control will be attained through implementation of the reliability and maintainability requirements that are provided in the subcontract or in the supplier procurement document. These requirements will be tailored to impose specific reliability and maintainability requirements as a function of criticality, type of hardware, complexity, and previous experience with the supplier and the hardware. Control over subcontractor/supplier design, parts/materials selection, and processes will be maintained by experienced teams and the need for any program adjustments will be implemented.

Our reliability team will be responsible for obtaining, from NASA-GSFC adequate reliability data on any parts or components furnished by the government (GFP) which may be needed by us to perform the contractual reliability requirements.

The reliability/maintainability design criteria developed as a result of analyses performed during Phase B will be reviewed and updated, incorporating the results of additional trades and analyses, to support the AMPS detail design.

Reliability personnel will provide a continuing review of both in-house, subcontractor/supplier and instrument contractor design activities to ensure incorporation of the reliability and maintainability criteria and requirements in the AMPS payload design.

Failure Mode and Effects Analyses (FMEA) will be performed by reliability engineers in conjunction with subsystem designers on the AMPS FSE including all external interfaces and GSE. These FMEA's will be used to develop a Critical Items List (CIL) which consists of a single failure point summary (SFPS) and a summary of redundant elements in life-limited and mission essential components. Safety engineers will support the FMEA effort to provide a basis for the system safety hazards analysis.

An FMEA will also be performed on the FSE/GSE/INSTRUMENT/SPACELAB/SHUTTLE interfaces and integrated with the FSE, GSE, and Instrument FMEA's into a total AMPS Payload FMEA. This AMPS payload FMEA will provide a basis for the total AMPS payload safety analysis, systems test program, and mission operations planning.

A parts, devices, and materials program will be established and implemented in accordance with NHB 5300.4 (1D-1) and GSFC requirements. This program will consider the FSE/GSE new designs, existing designs, and off-the-shelf hardware items individually to allow selection of the most cost effective approach for each item.

Reliability/maintainability liaison and support to AMPS FSE system/subsystem/component design, fabrication, and test will be provided on a continuous basis throughout the program. This will include design review support, a failure reporting and corrective action program, and a system for responding to all NASA ALERTS. The maintenance/repairability features of the FSE design and the capability to check all redundant elements will be verified during the test phases, and FSE maintenance requirements will be updated to provide inputs to the logistics and maintenance/refurbishment plans. A complete problem/failure history and closure status will be maintained and included in the readiness review package.

Reliability/maintainability will support the FSE, GSE, instrument, and AMPS payload design reviews, monitor all AMPS payload integration

and test activities, and support the payload readiness review. This will include failure reporting and corrective action and problem/failure history and status for the FSE, instrument, Spacelab, and Space Shuttle interfaces.

The FSE and instrument maintenance and refurbishment requirements will be reviewed and integrated into the AMPS payload maintenance requirements which will provide an input to the integrated logistics, maintenance/refurbishment, and mission operations programs.

B. Quality Assurance

For Phase C/D of the AMPS payload program, the quality plan which follows has been developed to define and describe the quality assurance functions which will be implemented to assure the quality and reliability of the AMPS hardware. The scope of the plan encompasses all aspects of the program beginning with preliminary design and continuing through to flight operations and post-flight inspection, refurbishment, test, and checkout. The plan will also provide for the early detection, documentation and analysis of nonconformances and anomalies and for timely and effective remedial and preventive action.

All quality assurance operations will be managed and controlled by the Product Assurance Manager. Reporting directly to the Program Director, he will have both the responsibility and the authority to evaluate quality problems and initiate solutions.

1. Quality Plan--The quality plan will be the primary governing and planning document controlling quality assurance activities. The plan defines the quality tasks to be performed throughout the contract, describing the controls to be implemented to assure that all hardware and software meets engineering and contract specifications. The detailed instructions are contained in Martin Marietta Standard Procedures and Quality Procedures which will be available for customer review. Revisions to these procedures, where needed to implement requirements unique to the AMPS program, will be prepared and released as program-unique appendices or as program procedures. Procedures that define or require customer involvement will be available for customer evaluation. Quality assurance requirements unique to an off-site operation such as GSFC or KSC will be addressed in appendices to the quality plan, to be developed after contract go-ahead.

2. Quality Controls--Management control of quality assurance operations will be achieved thru the implementation of Martin Marietta procedures and standards. Standard procedures describe management techniques and systems to be used in conducting the company's business and generally affect all departments of the company. Quality procedures define and describe the policies, systems, methods and responsibility assignments through which the Quality Department assures satisfaction of the quality requirements of the contract and the company. Quality

technical instructions provide uniform instructions where standardized methods are necessary. The Workmanship Standards Manual augments company acceptance criteria for workmanship where the basic measure of quality is largely subjective. Quality requirements imposed on inhouse operations and on suppliers are tailored to the requirements of the specific item to be produced or procured by:

a) Insertion of specific inspection requirements in fabrication plans and test procedures;

b) Issuance of program-unique program procedures and quality procedure appendices;

c) Issuance of quality project directives approved by the Product Assurance Manager;

d) Quality requirements coding of purchase requisitions.

3. Nondestructive Evaluations (NDE)--Specific nondestructive evaluation requirements and techniques will be identified during the preliminary design review. Design, manufacturing and quality engineers will participate. This group constitutes our NDE review board and formulates NDE development planning.

For NDE we have Quality Technical Instructions (QTI) which specify general NDE. Special NDE requirements are listed in the engineering drawings. The requirements are met by Quality Laboratory procedures which include the fabrication of special standards, specific equipment and controls, operational instructions and special people certification requirements. These procedures require the use of enough samples to demonstrate that we have inspection reliability and confidence to the level of program requirements.

4. Quality Program Audit--The existing audit programs will be utilized for the AMPS program. They include a division-wide, systematic appraisal of operational performance to assure that management objectives, contract commitments, product integrity, and mission objectives are successfully and effectively achieved. Also, a Quality Department self-audit program, which complements the Division audit program, is performed within Quality and of Quality's interfaces with other departments. This audit program reviews applicable company procedures for compatibility with contractual quality requirements, to verify that the Quality Department is, in fact, complying with these procedures and contract requirements. These audit programs are planned and scheduled. Results are documented, and reviewed by upper management. In addition, unscheduled audits are performed at the direction of upper management to provide instantaneous assessment of performance or to determine the magnitude of a real or potential problem.

Auditing of supplier activities is normally conducted concurrent with source inspection activities. This supplier audit program does

not preclude unscheduled or special audits by Program management personnel or others as the need may arise either to resolve a problem at the supplier's or to "audit the auditor".

5. Design and Development Controls-- Quality engineers will review contract and engineering specifications, drawings, fabrication plans, test procedures and other technical documents. These reviews will assess the compliance level of program technical documents with established quality and design control criteria.

Quality personnel will participate in pre-release reviews of drawings and in the preliminary and critical design reviews with the NASA. In preparation for the preliminary and critical design reviews, Quality will review drawings and process plans, FMEAs, and the nonconformance history of similar systems, components and parts, using a checklist developed specifically for this purpose.

Prior to an acceptance review, the Product Assurance Manager will assure that the following items have been accomplished: evaluation of the end item acceptance test results; anomalies encountered; failure history, and remedial and preventive actions; status of all open work, including tests and identification of those which constrain further activities, such as integration or flight; identification of waivers and deviations to contract requirements and specifications, and verification of the basis for approval; status of limited life components and their remaining life; identification of shortages, open work items, and the schedule for completion; development of a form DD250 indicating shortages and deficiencies which must be resolved prior to further activities, such as flight readiness, verification that departures from specifications and drawing requirements have been processed; verification that all data packages and support manuals for the operational checkout, and maintenance of the end item are complete, compatible and accompanying the hardware, and that all shipping requirements have been met.

6. Identification and Data Retrieval--Identification and data retrieval systems have been developed which are compatible with engineering documentation and configuration management systems and provide for identification to which procurement, fabrication, processing, inspection, test, and operating records can be related. The systems also provide the means for locating articles and materials in end items. When required by engineering drawings or procurement specifications, items will have identification traceable to their origin such as: manufacturer's data; date purchased; lot number; inspection and test data; or other pertinent information, as applicable. EEE piece part identifications will be recorded in fabrication records to permit tracing backwards from fabricated hardware to the manufacturing records for the piece parts. As required, limited life items, serialized components and other critical hardware identifications will be recorded in the fabrication records to allow traceability from the end item back to the tests performed, the test results, and the specific

processes employed in the manufacture of each lot of parts.

7. Procurement Quality Activities--Responsibility for the overall planning and management of procurement quality activities is vested in the Product Assurance Manager. He will provide program direction for the detailed planning and implementation of the procurement quality activities for the program.

Quality will participate in the selection of suppliers of articles and materials procured to Martin Marietta drawings and specifications. Historical data from supplier quality performance reports, pre-award surveys, and technical reviews will be used in the supplier selection process. Information supplied by the NASA will also be evaluated. Procurement sources for standard hardware and raw materials will be selected on the basis of the Approved Vendor List (AVL), Qualified Products List (QPL) or supplier performance records. Procurement sources for Military Specification parts will be selected from suppliers listed as qualified to furnish that part.

All purchase requisitions applicable to the program will be reviewed by our Quality personnel. From a review of drawings and other technical documents, from participation in design reviews, and from contract requirements they will determine the quality requirements to be imposed on the supplier of each item. These quality requirements will then be added to the purchase requisition. Source inspection will be provided at the supplier's facility as required. Source inspection will include, as appropriate, review of special processes, review of manufacturing/inspection plans and procedures, review of test plans and procedures, inspection and acceptance of hardware and test results, and verification of hardware documentation prior to delivery. Through their Perpetual Evaluation Program (PEP), our Quality Source Representatives will perform planned, continuing evaluation of the supplier's activities, which will provide documented control of product and processes.

All hardware and material procured for the program, and all GFE and GFP provided for the program will be inspected upon receipt at Martin Marietta by Receiving Inspection, a Quality Department organization. Inspections are performed to Receiving Acceptance Plans (RAP) written by Quality and developed from reviews of drawings and specifications and from the quality assurance and documentation requirements imposed upon the supplier.

Conforming items are identified by acceptance stamping the item or its associated documentation except that metallic materials are not acceptance stamped. They are coded and acceptance is shown on the receiving report and the inspection record card. Nonconforming items are so identified, segregated pending disposition, and documented in accordance with paragraph IX-B-10, Nonconforming Articles and Materials.

The Receiver (a copy of the Purchase Agreement) and the RAP constitute the primary receiving inspection and test records. Results are recapped onto inspection record cards which, by part number and supplier provide summary records of quantities received, dates inspected, and inspection results. Data from the records are used to generate supplier evaluation reports for management assessment of supplier performance.

Data packages received with procured hardware are reviewed for completeness and accuracy and, if acceptable, are retained by Program Quality or the Quality Data Center.

The summary records described above together with rejection history from other sources (e.g., source inspection) are compiled into a tab run keyed to supplier. A folder is also maintained for each supplier containing otherinformation relative to the supplier such as PEP findings, survey results and the like. All of these data and records are available for use in the selection and qualification of procurement sources.

8. Fabrication Quality Operations--Fabrication plans will be used to control and document fabrication, assembly, installation, and inspection operations. Fabrication plans and changes are reviewed and approved by Quality for compliance with engineering requirements and for inclusion of inspection check points, before release. Fabrication plans become the historical record of fabrication, assembly and installation operations and inspections performed, and are maintained on file.

Articles and materials will be stored in controlled areas. Conforming items, or their containers, are acceptance stamped. Quality will verify that articles and materials issued against a fabrication plan are correct and conforming and that age-or use-sensitive items have sufficient remaining life or cycles. Limited life items are identified by date-of-expiration labels. Items requiring contamination control are environmentally protected and identified by tags indicating cleaning level status. Articles or materials requiring a temperature-controlled, contamination-controlled or other special environment for fabrication or processing will be inspected, tested, repaired or modified in a similar environment to the extent necessary to prevent quality degradation or deterioration of cleanliness level.

Life/time/cycle limitations will be recorded in the equipment log and nonconforming articles and materials will be so identified and segregated to the extent possible pending disposition. Quality will maintain surveillance of stockrooms to assure proper storage, documentation and identification of limited life items.

Contamination control specifications applicable to the AMPS program will be defined in the engineering drawings, which will specify the pertinent Engineering Process Specifications (EPS). Instructions to personnel performing and inspecting cleaning operations are found

in Manufacturing Processes (MP). They bear the same basic numbers as the related EPS. Fabrication plans and test procedures will call out the MPs to be used. Quality will enforce all contamination control requirements. The Quality Laboratory will verify and certify the cleanliness of all fluids used on AMPS hardware and will determine the particulate count of clean rooms. Suppliers of contamination controlled hardware will have their cleaning operations and processes surveyed and approved in writing by us before cleaning operations begin.

Manufacturing processes, where the quality of the operation cannot be determined by inspection alone, and inspection processes such as radiographic inspection, dye penetrant inspection, or magnetic particle inspection, are defined in EPS. MPs define in detail the step-by-step operations to be performed, the tools required, necessary materials, special requirements certifications, environmental controls, sample requirements, inspection requirements, and workmanship standards. MPs and revisions thereto are reviewed, validated, and approved by Quality before release. Applicable MPs and mandatory product inspection points are specified in fabrication plans.

Hardware integrity is assured by process control, by process sampling, and by nondestructive evaluation techniques. Overall hardware integrity definition, assessment, validation and applications are integrated into EPSs, MPs, and test procedures to meet program requirements.

Equipment used in special processes is certified by Quality when the process results depend upon equipment performance, e.g., heat treat equipment and clean room facilities. Qualification and recertification requirements are established in the EPS and MP. Recertification is also required when test results or inspections indicate a need for changes to the normal process or when equipment changes may affect the process. Certification records are maintained by Quality.

Standards of workmanship have been developed for selected processes such as solderless connections, soldered connections, printed circuit board packaging, conformal coating, microelectronics assembly. These standards augment acceptance criteria where the basic measure of quality is largely subjective. Applicable workmanship standards will be identified by reference in MPs or fabrication plans and compliance with these standards will be a prerequisite to acceptance. Workmanship standards are updated as required and will be available for review by the NASA.

Temporary installations will only be allowed by engineering drawing, fabrication plan, test procedure or MARS/DR. All temporary installations will be recorded in the equipment log and the entry will remain open until the temporarily installed item is removed. Any temporarily installed item which will remain installed at the time of shipment of the end item from Martin Marietta will carry a distinctive identification with visual impact and be recapped as an open item in the end item equipment log.

9. Testing, Inspections and Evaluation--In order to demonstrate and verify that contract, drawing and specifidation requirements have been met for all deliverable hardware and software, the previously described Purchase Agreements, RAPs, fabrication plans, EPSs, MPs will provide a documented trail of written instructions and evidence of compliance from initiation of the purchase agreement thru fabrication and assembly. The manufacturing flow plan which has been developed for the fabrication, assembly, integration and test operations will include inspection points at all levels. Engineering, supported by Quality, will develop an integrated test plan which will identify all testing requirements including production in-line testing, acceptance testing, component testing and systems testing for the program. From this test plan and the appropriate test specifications, individual test procedures will be developed which will provide all of the detailed information and direction necessary to the proper execution of the tests. Testing of components, subsystems, the FSE system and the integrated AMPS payload will be witnessed by Quality. Quality will verify hardware configuration prior to testing, will ensure the documentation of test failures, will witness troubleshooting and will approve corrective action taken to prevent recurrence.

The inspections and tests performed on deliverable hardware will verify compliance with requirements. Approved fabrication plans and test procedures will be used to control all inspection and test operations. Quality inspections will verify the acceptability of the fabrication operations and acceptance stamp applicable steps in the fabrication plan. Test procedure certification sheets will be signed by the responsible organizations upon satisfactory completion of the test and closure of open items.

Hardware integrity will be strictly maintained during test. Rework, repair, modification, adjustment or replacement will not be permitted except as specified in controlling documentation. Test control and discipline is basically the responsibility of the testing organization, but will be closely monitored by Quality.

Environmental controls will be exercised when required to protect product quality or control contamination. In the event of nonconformance or test anomaly, documentation and control will conform to the requirements of paragraph IX-B-10, Nonconforming Articles and Materials. Reinspection and retest requirements will be included in the controlling documentation.

Following the testing operation, Quality will ensure proper disposition of the test hardware; ensure that remedial and preventive action has been accomplished relative to nonconformances; and ensure that test results are accurate, complete and traceable to the tested hardware.

Access to the AMPS payload during assembly, integration, test and checkout will be limited. Special environments will be maintained as

specified in the engineering drawings.

10. Nonconforming Articles and Materials--Nonconformances of articles and materials will be documented and the item so identified, segregated to the extent practicable, and controlled pending disposition. The nonconforming hardware, and/or the accompanying documentation, as appropriate, will initially be identified as nonconforming by "D" stamping. An interlocked triangle stamp indicates that the hardware has been dispositioned. An interlocking acceptance stamp indicates reacceptance.

Articles that have received government acceptance will be treated as described in Paragraph IX-B-15, Government Property Control.

Nonconforming hardware will not be shipped with an open nonconformance without prior government approval.

A system will be used which will provide closed loop documentation for recording, reporting, analyzing, correcting, verifying and feeding back data on nonconformances. At Martin Marietta, the Martin Automatic Reporting System (MARS) is the form used for documenting, reporting, dispositioning, controlling, and providing corrective action for significant problems, acceptance test failures and anomalies, Material Review Board actions, and where a detailed engineering disposition is needed.

For nonconformances that do not require MARS action, the Discrepancy Report (DR) may be used. DRs may be used to describe conditions which require work, calibration, maintenance, and/or authorization for use of facilities, tooling and test equipment. Finally, DRs may be used to describe problems associated with documentation when hardware nonconformance is not involved.

The MARS will be used exclusively during the operations phase of the contract. Nonconformances will be accumulated by Program Quality in summary reports to program management. Trends will be charted to detect adverse quality developments. MARS are reviewed by Quality to assure the adequacy of disposition and corrective action. The DR will also be reviewed for correct application, trends, and requirements for corrective action. If corrective action is required or unacceptable trends develop, remedial action will be initiated.

Failures will be assessed by Engineering and Quality for formal failure analysis requirements. Failure analysis reports will be approved by Program Quality. Functional nonconformances for which we recommend a disposition to repair or use as is, and the resulting condition adversely affects the requirements of the contract, will be submitted through the Contracts Department for a waiver approval.

A Material Review Board will be established for the program. The MRB will disposition all nonconformances submitted to it for MRB action.

The MRB will consist of one Quality member, one Engineering member, and the delegated Government quality representative. Manufacturing and other technical organizations may participate in MRB deliberations as consultants, but may not vote.

All MARS that have received full MRB action are considered to be material review records and are retained as such. The MARS is considered to have had full MRB action when the designated MRB members have signed in the appropriate blocks of the MARS.

11. Metrology--All inspection standards, gages, measuring and testing equipment, and tools necessary to determine conformance to specification, drawing and contract requirements will be selected, evaluated, maintained and controlled.

Measuring and testing equipment and tools are inspected and calibrated as applicable before quality acceptance. All new equipment and tools are entered into the mechanized property accountability system and those calibrated are added to the mechanized recall system. An initial calibration interval is specified by the Metrology Laboratory.

Measurement standards and equipment identified for use on the AMPS program will be evaluated by Quality for intended operating use to verify that the equipment will measure the characteristic to the required accuracy: the hardware to be measured and the measuring equipment are compatible; and operating instructions are correct and complete.

Measurement process random and systematic errors will not exceed 10% of the tolerance of the characteristic being measured. Quality will verify that this accuracy requirement has been maintained during its review of process plans and test procedures.

Calibration measurement process random and systematic errors will not exceed 25% of the tolerance of the parameter being measured, within the limitation of the state of the art. Where this ratio cannot be maintained, measurement limits will be established so that they fall within a band defined by reducing the allowable tolerance by the estimated uncertainties of the measurement process. Where this is not feasible, authority for exception will be requested of the NASA.

All standards and measuring and testing equipments receive inspections and calibrations at regular intervals determined by instrument reliability, accuracy requirements and usage. Calibrations are performed to written procedures/instructions which define the specifications and tolerances, the standards and test equipment to be used, and test methods. A certificate is applied to each item of calibrated equipment indicating the date calibrated, next calibration due date, and the stamp of the technician certifying the calibration. If a deviation from calibration specifications is approved, the deviation will be stated on the calibration certificate.

The calibration laboratories are environmentally controlled to ensure compatibility with the accuracy and design characteristics of the standards and equipment in the laboratories.

If test equipment exceeds one and one-half times its allowable tolerance limits as received for recalibration, the cognizant Quality Manager is notified. He will effect a review of the uses made of the defective equipment to determine what measurements are suspect because of the nonconformance.

12. Stamp Control--Inspection stamps, planning stamps and sealing devices will be used to indicate the acceptance status of articles, materials and documentation. Our Quality stamps are instantly identifiable and traceable to the responsible individual. Quality stamps are controlled by Quality and records are maintained to account for all stamps.

13. Handling, Storage, Preservation, Marking, Labeling, Packaging, Packing and Shipping Operations--Special handling and transportation, storage, preservation, marking, labeling, packaging, packing and shipping requirements will be specified in the engineering drawings. These requirements will be reflected in purchase orders, fabrication plans, test procedures or special procedures. Quality will monitor these operations to assure compliance.

Besides handling requirements, engineering drawings will specify the handling fixtures and test fixtures to be used on the program. Necessary fixtures will be designed and built. All handling equipment will be proof loaded and Quality will verify the proof load before use. Fabrication plans and test procedures will spell out instructions for handling the hardware during integration, test, packaging, packing and shipping. Quality will monitor handling operations.

Articles and materials will be stored in dedicated, controlled areas. Quality will verify that environment-sensitive items are stored in suitable environments. They will also verify that the containers of ag-sensitive items are so marked and that date of manufacture and life expiration date are clearly indicated. Special storage/maintenance/periodic inspection/periodic test requirements will be specified on engineering drawings and appropriate procedures generated for performance.

Engineering drawings will specify the preservation, marking, labeling, packaging and packing requirements. These requirements will be reflected in fabrication plans, test procedures or special procedures. Quality will verify that all requirements have been satisfied.

For all AMPS hardware shipped from MMC, Quality will verify that the hardware meets all drawing, specification and contract requirements, that all required fabrication, assembly, integration and testing is

complete and acceptable, and that the hardware is in all respects ready for shipment. The documentation accompanying the hardware will be reviewed by Quality to verify that it is complete and has been accepted by Quality and by the Government as required. The documentation included in the shipment will be that specified in the contract.

14. Sampling Plans, Statistical Planning and Analysis--The use of sampling techniques will be limited to receiving inspection. Sampling plans used at MMC are based on MIL-STD-105D. No statistical analyses are planned for inspection operations.

15. Government Property Control--Government property received at MMC will be controlled as specified in Standard Procedures and Quality Procedures.

Government property received at Martin Marietta will be processed through Receiving Inspection to Receiving Acceptance Plans (RAP) prepared by Receiving Inspection in accordance with direction from Quality. If an equipment log is not furnished with the GFP, a history sheet will be originated at Receiving Inspection to document the history of the hardware while at Martin Marietta and to record maintenance, calibration, and inspection. The GFP will be identified, if not consumable, and will be incorporated into our property accountability system. GFP will be stored in the segregated, controlled program stockroom. Stock records will be initiated and maintained for accurate accountability.

Any damage, malfunction, test failure or other GFP anomaly will be documented on a MARS and the MARS presented to the Government representative. If MRB action is requested by the Government representative, the MRB will perform MRB action and determine a recommended disposition. If the Government representative concurs, disposition will be effected as described in paragraph IX-B-10, Nonconforming Articles and Materials. If not, the Government representative will direct disposition of the hardware.

GFP will not be repaired, modified, reworked, replaced, or otherwise dispositioned except as authorized by contract or directed by the government.

C. Safety

The AMPS safety program has been established in recognition of the need for systematic and effective methods to coordinate the efforts of all technical organizations in order to ensure timely identification and implementation of safety criteria and requirements, and to minimize oversights that could contribute to systems failure or loss, equipment damage, or injury to personnel. The AMPS safety program, as outlined herein, will be further defined in the AMPS Program Safety Plan and implemented as an integral element within the total systems engineering and management process throughout all phases and activities of the AMPS project, including those required to support the integration

and operations effort for the AMPS program. The AMPS safety program will be implemented in accordance with requirements defined in NHB 5300.4 (1D-1) and established safety policy as defined in Martin Marietta Operation Instruction PO-6-(1)-D1.

1. Management and Organization Approach--An AMPS Project Safety Engineer will be assigned to perform comprehensive planning and analysis, and to ensure that all safety criteria and requirements applicable to flight and ground hardware and operations are identified and implemented throughout the contract period of performance. The Project Safety Engineer will be responsible for directing the FSE and AMPS payload safety effort, coordinate the instrument contractors safety activities, and serve as the focal point for all safety matters pertaining to the AMPS payload project. He will call upon area safety engineers and other safety specialists within the Denver Division safety organization, as required throughout the program, to perform specific phase-related duties or specialized tasks in support of the project. Through the Project Safety Engineer, the combined experience of Denver Division safety personnel will be available to the AMPS project. The primary benefit of this organizational approach, coupled with detailed planning and scheduling of safety tasks, is to provide the AMPS project with the most appropriate safety personnel to perform phase-related or specialized tasks while maintaining continuity and visibility of overall AMPS safety program activities and status.

2. System Safety--Systematic and progressive hazard identification and analysis activities will be performed for all flight and ground systems, subsystems and interfaces and for all planned flight and ground operations. These activities will be keyed to overall project design and development schedules in order to provide maximum effectivenss in the elimination or control of hazards in accordance with the established hazard reduction precedence sequence defined in NHB 5300.4 (1D-1). This approach also provides effective utilization of manpower through establishment of safety task priorities through a building block concept. The preliminary hazard analyses performed by the FSE and instrument contractors during the program definition phase will be expanded and updated into an AMPS payload hazards analysis. Inherent hazards associated with the various subsystems and operations (energy sources, environments, etc.) will be identified and documented. Based on the results, safety design criteria and requirements will be identified for immediate use by contractor project engineering organizations, and priorities will be established for more detailed analyses to be subsequently performed. This will provide the design organizations with safety criteria which can be used to minimize oversights and assure maximum safety consistent with program objectives and cost constraints designed into the system prior to design release to manufacturing. The hazard identification and analysis effort will use, to the maximum extent, the outputs of other activities such as systems design analyses and FMEAs. Specialized safety data used in support of this effort will include both Government and Martin Marietta Safety Standards,

Manuals, Handbooks and System Safety Checklists. Applicable safety criteria will be included in design specifications, procurement drawings, process specifications and similar documentation as appropriate.

In order to ensure an integrated effort throughout the AMPS project, all potential hazards, identified as level a and b in accordance with NHB 5300.4 (1D-1) definitions, will be documented on hazard analysis worksheets and issued for coordination or action by appropriate contractor subsystem management or discipline specialists. Upon completion of this coordination and validation process, a formal tracking number will be assigned. All responses to actions will be reviewed by system safety personnel for adequacy in the elimination or control of identified hazards. At such time as a hazard analysis is completed to the point of closure in accordance with criteria as defined in NHB 5300.4 (1D-1), or Conditional Closure as defined herein, hazard analysis worksheets will be updated to include the disposition based on design changes, analyses, tests or other actions taken. The disposition of each hazard analysis will be formally approved by both systems engineering management and the project safety engineer. Hazard analyses will not be officially closed until the disposition has been approved by GSFC.

Conditionally Closed is a term used by us only for tracking purposes, as an aid in establishing priorities for effective use of manpower, and as a communications tool and management indicator of safety program performance. A hazard analysis is designated as Conditionally Closed when the primary analysis effort has been completed to the extent of identification and acceptance by systems engineering management and the project safety engineer of corrective actions which are considered necessary to eliminate or control an identified hazard, and for which final closure is dependent upon implementation of the corrective action or controls. An exception would exist in cases where system level verification or action would be required in order to resolve a hazard affecting interfacing hardware for which we are not responsible. At such time as a hazard analysis reaches a point of completion that it may be designated as Conditionally Closed, it will be approved by systems engineering management and the project safety engineer and submitted to GSFC with appropriate supporting data. This approach will provide GSFC with progressive visibility of hazard analysis activities and will provide a basis for precoordination and technical evaluation of anticipated closure action.

Hazard analyses will be summarized in a project hazard catalog in order to provide visibility to management of all hazard analyses and their status in sufficient detail to eliminate the need to review detailed hazard analysis worksheets and supporting data. The Hazard Catalog will reflect risk decisions made by project management and will be structured to provide a quick reference to each hazard analysis by number, latest revision, date of issue, hazard description, original and current hazard level (will reflect progress achieved in

elimination or reduction of risk), actions taken or in progress, and disposition. Also, the hazard catalog will reflect residual hazards and other pertinent data. The Hazard Catalog will be used as the primary document for tracking and statusing hazards and will be periodically submitted to GSFC as an input to major design and project milestone reviews.

3. Trade Studies--Directives are issued defining scope of effort, requirements and responsibilities for the performance of formal trade studies. System safety personnel will progressively review documentation developed by trade studies to ensure safety requirements and considerations are factored into such activities. Trade studies involving significant safety considerations will require direct participation by system safety personnel.

4. Review and Evaluation of Changes--Design changes will be reviewed by system safety personnel to ensure that safety requirements are adequately considered, and to ensure that potential hazards which may be introduced by the change are identified. Changes affecting the previous safety status of the hardware or invalidating or otherwise affecting the technical accuracy of closure rationale for hazard analyses which may have been previously submitted to GSFC will be either reopened or updated to reflect such changes and resubmitted to GSFC.

5. Industrial Safety--Continuous maintenance of safety standards, a safety procedures and requirements manual, a radiological safety manual, and an accident-incident investigation handbook by the Denver Division central safety organization will provide up-to-date information for use by the project safety engineer and area safety engineers throughout the AMPS program. Existing safety policies, standards, requirements and procedures are in compliance with NHB 5300.4 (1D-1) and GSFC requirements governing such aspects as accident-incident investigation and reporting.

A Denver Division internal audit program is implemented to ensure compliance with the standards imposed by the Occupational Safety and Health Act (OSHA). The Denver Division complies with all applicable aspects of OSHA, including conformance to State plans and their attendant standards.

The Denver Division maintains its own fire protection organization, which includes facility equipment, vehicles, and personnel on duty 24 hours a day, seven days a week. All ordnance, chemical and other hazardous material storage areas, as well as manufacturing, test and office work areas are protected by either automatic fire detection and suppression equipment or by design, location, and 24-hour security surveillance, or both, as appropriate. Comprehensive procedures, training, auditing, and maintenance are major elements of the Denver Division's fire protection and security program.

Some specific safety tasks to be performed during the AMPS design and development phase, which will be further defined in the Project Safety Plan, are as follows:

a. Review and approve tooling designs.

b. Review training requirements, identify project peculiar safety requirements, and ensure implementation of training and certification requirements for personnel involved in such activities as fabrication, assembly, crane operations, handling transportation and storage of hazardous high cost or mission critical hardware.

c. Review and approve purchase requisitions and/or shipping requests for hazardous materials.

d. Review and approve manufacturing processes.

e. Perform monitoring and surveillance of manufacturing, test, product handling, storage, and office areas to ensure adherence with safety standards and requirements.

6. Test and Ground Operations Safety--Test plans, specifications and requirements documents will be reviewed and evaluated to ensure adequate tests are specified for materials, systems, subsystems, and critical devices or components under all anticipated environments. These reviews will ensure tests are adequate to determine such factors as degree of hazard or margin of safety in design. These reviews and evaluations will be an integral function of the progressive performance and refinement of FMEAs and hazard analyses. Requirements for special safety tests will be identified as required.

Ground support equipment, including facility support systems, will be evaluated for all planned ground operations and tests in order to identify hazards to personnel, flight or flight-type hardware, ground support equipment and facilities. Special emphasis will be given to ensuring protection of flight and flight-type hardware, from damage which could be caused by human error or ground equipment malfunction.

All procedures to be used for testing flight and flight-type hardware, and other procedures involving hazardous operations or tests as determined by review and evaluation of test data and performance of hazard analyses, will be reviewed and approved by safety personnel prior to their use. Tests and operations determined to be hazardous will include prerequisite requirements for safety surveillance or direct participation by safety personnel as a member of the test team, as appropriate. All procedures requiring validation will require a safety representative as a member of the validation team. Operational readiness inspection requirements will be identified for all hazardous operations and tests based on reviews of test plans, hazard analyses and final review and approval of test procedures. Testing will be performed only by approved procedures. Safety personnel will review and approve all changes to procedures.

X. FACILITIES

This section will encompass the facilities program analysis and planning required to support the AMPS Phase C/D Program. Included will be analyses required to determine the best approaches and planning required for design and development of the facilities necessary to support the ground operations phases of the AMPS program. Facilities requirements, approaches, and implementation techniques which follow are subject to iterations as the elements of the program are better understood.

A. Requirements

Requirements for facilities will be determined by analyzing the AMPS ground operations. Facility requirements will be determined by evaluating the Phase B program system and subsystem results and iterating the same r refinement. Facilities which will be considered will include those necessary to support design, development and integration activities. Requirements will be generated which include facility floor space requirements, facility commodities, etc., for each site.

1. Groundrules -- Certain groundrules or guidelines have been identified which will be used as a basis for the requirements initiating the phase C/D program. Further detail to these requirements will be generated as the phase C/D matures.

a) The design and development of instruments/FSE will include the use of universities, development contractors and the GSFC Certification Laboratory.

b) The prime contractor's facility will be available for Instrument/FSE System's development testing, but will be required for Level IV activities.

c) Facilities at each site will include receiving and inspection areas, test areas, bonded storage for instruments, GSE storage area, office space for personnel involved in program planning, testing and data evaluation to the level required for program support.

d) A Payload Handling Facility (PHF) will be required to support off-line dedicated AMPS activities at KSC in order to support the currently planned Space Shuttle Program Flight schedules. This facility will be large enough to handle the buildup-tear down of two AMPS payloads simultaneously.

e) Wherever practical the AMPS program will utilize currently existing or planned facilities.

f) For Level III/II and Level I activities the AMPS program will require no special facility requirements.

g) The AMPS Payload Handling Facility will perform maintenance and refurbishment activities between flights and provide an AMPS Logistics Center.

h) No special AMPS Facilities will be required at WTR as it is assumed that all payload activities can be accomplished at the Spacelab facility.

2. Trade Studies -- Facility trade studies will be performed comparing the most economical and technically feasible approaches for completing tasks versus the facility costs for utilizing a particular facility approach as well as the impact upon the entire AMPS program. These trade studies will be coordinated with all elements of the AMPS project to be certain that complete coordination has been established.

B. Planning

Facility planning during the Phase C/D programs will be based primarily on the AMPS Payload Requirements as they evolve and the groundrules defined in Section X-B-1. Maximum use will be made of the facilities definition employed during the Phase B activities to fully utilize the experience gained.

As the program is defined in greater detail, more detailed facility plans will be developed. For example, definite dates will be developed on the time that the specific entities of the Payload Handling Facilities will be required and the floor space and commodities for these support areas. This activity will be an iterative process of the procedures developed during the AMPS Phase B Study. To be certain that planning activities proceed on schedule monthly planning meetings will take place during Phase C and bi-monthly during the early part of Phase D. This close coordination between the contractor and the NASA personnel will provide the necessary management tools to maintain visibility to incorporate the lowest cost and technically feasible approaches possible. To be certain that planning activities track the requirements existing or planned facilities capabilities will be compared to the needs, such that the best solution is reached.

To adequately document the meetings and be certain the Phase C/D program plans are proceeding on schedule monthly facility schedules will be maintained.

An example of a currently planned AMPS mission schedule is presented for the first AMPS flight, showing the need date for the facility milestones known at this time.

C. Implementation

To meet the facility needs for the Phase C/D program, the prime contractor will prepare and maintain the planning, requirements and implementation documents, schedule meetings for the necessary parties

involved, and perform the coordination required to schedule the facilities so that they are available at the necessary times. The prime contractor's early coordination with the development contractors will aid in identifying their needs for facilities later in the program.

D. Currently Planned Resources

At the completion of the Phase B study certain facility requirements were defined which were needed in support of AMPS activities at the various locations where AMPS elements through the integrated system would be used. These facilities will be the baseline for the Phase C/D facility analysis and will be continuously monitored to verify that they are still available and will still meet the known requirements. Specifically, these consist of the following.

1. Development Contractor's Facilities -- The development contractor's facility for some instruments may not be adequate to complete qualification and acceptance testing. Therefore, prior to delivery to the prime contractor's site the instruments will be further tested at the GSFC Certification Facility.

2. GSFC Certification Facility -- This facility is capable of certifying instruments and instrument systems prior to delivery to the prime contractor's Level IV site. The facility can perform thermal vacuum, vibration, acoustics and other environmental testing required for flight certification.

3. Prime Contractor's Facility - These facilities will provide a Class 100,000 high bay area, sufficient airlocks for packing and unpacking pallets, instrument systems, clean assembly areas and support capabilities for instrument systems/pallet level environmental testing. Currently, use is anticipated of the Man/Computer Interactive Laboratory for C and D development, the thermal vacuum facility for instrument system level tests, and the Vibration/Acoustics Facility for instrument systems/pallet level testing.

4. KSC Facilities -- A Payload Handling Facility is required at KSC to support AMPS dedicated off-line activities prior to Level III/II testing. This facility does not exist yet and may consist of one of the existing facilities such as SAEF #2 or the A-O hanger or it may have to be a new facility. All other known AMPS facilities at KSC exist and these consist of the O&C Building, which is required to support the currently planned level III/II Shuttle/Spacelab activities and all payloads; the SPF, where the Spacelab/AMPS will be installed into the Space Shuttle Orbiter, although minimum payload activity is anticipated here; and the PCR, where the payload may require servicing but the only anticipated facility requirement is cryogenic servicing.

XI GROUND OPERATIONS

The ground operations activities provide the preflight ability to build up a Spacelab payload into a fully integrated Shuttle payload operational unit, and the post mission maintenance, refurbishment, and payload preparation for reflight. The AMPS ground operations flow is shown in Figure XI-1. This flow identifies the flight hardware integration site and facility locations. The ground operations activities described forms the basis of the AMPS requirements for integration, maintenance and refurbishment as they relate to programmatic considerations with respect to facility usage, manpower, support equipment, transportation and logistics.

The AMPS ground operations flow shown in Figure XI-1 is based on the requirements established in the Spacelab Payload Accommodations Handbook, May 1976; the Space Shuttle System Payload Accommodations JSC 007700, Volume XIV, Rev D; the KSC Spacelab Operational Turnaround Allocation Schedule, April 16, 1976; and the KSC Launch Site Accommodations Handbook For STS Payloads, Rev 3, June 1976, K-STSM-141. The integration levels shown are as follows:

1) Level IV -- AMPS payload buildup and integration test and checkout activities "off-line" from the normal Spacelab and Shuttle time critical, turnaround "on line" sequence of events.

2) Level III -- Spacelab payload buildup integrating the Spacelab pressure module, experiment racks, Payload Specialist Station (PSS) modules and AMPS pallet train onto the automatic checkout equipment stand forming the AMPS Spacelab payload. This activity is an "on-line" Spacelab function.

3) Level II -- AMPS Spacelab payload integration test and checkout including mission sequence simulation and weight and center of gravity verification. This activity is an "on-line" Spacelab function.

4) Level I -- Integration of the AMPS Spacelab payload into the Shuttle Orbiter, and the associated interface verification, and is an "on-line" activity.

After completion of these four integration levels the Orbiter must be integrated with the Shuttle booster systems and transported to the launch pad for launch preparation activities and final payload servicing, also an "on-line" activity.

The post mission ground operations start upon landing, however, the first payload access will be after the Orbiter is transferred to the Orbiter Processing Facility (OPF) for removal of the AMPS Spacelab payload. Upon removal from the Orbiter the payload is transported to the Spacelab Processing Facility (SPF) for demating of the AMPS

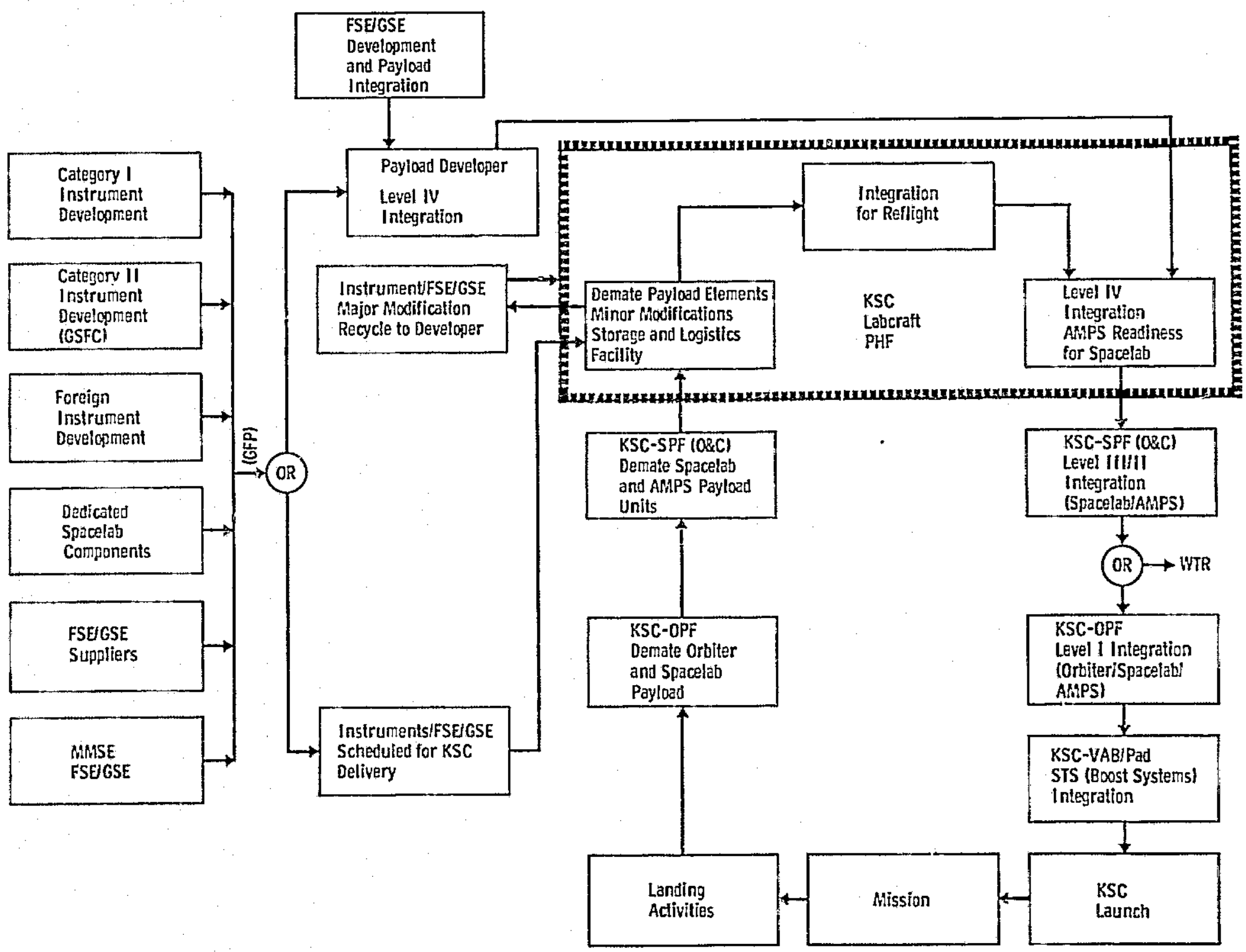


Figure XI-1 AMPS Ground Operations Flow

experiment racks, pallet train, and other AMPS peculiar equipment from the Spacelab pressure module, completing the on-line Shuttle activities. The AMPS payload equipment is transferred back to the AMPS Payload Handling Facility (PHF) for initiation of the maintenance and refurbishment activities associated with preparation for reflight, storage or a combination of these two activities.

The following paragraphs will provide a detailed description of the ground operations activities and requirements for the AMPS Spacelab payload. Ground operations alternate approaches will also be addressed as a final subject of this section.

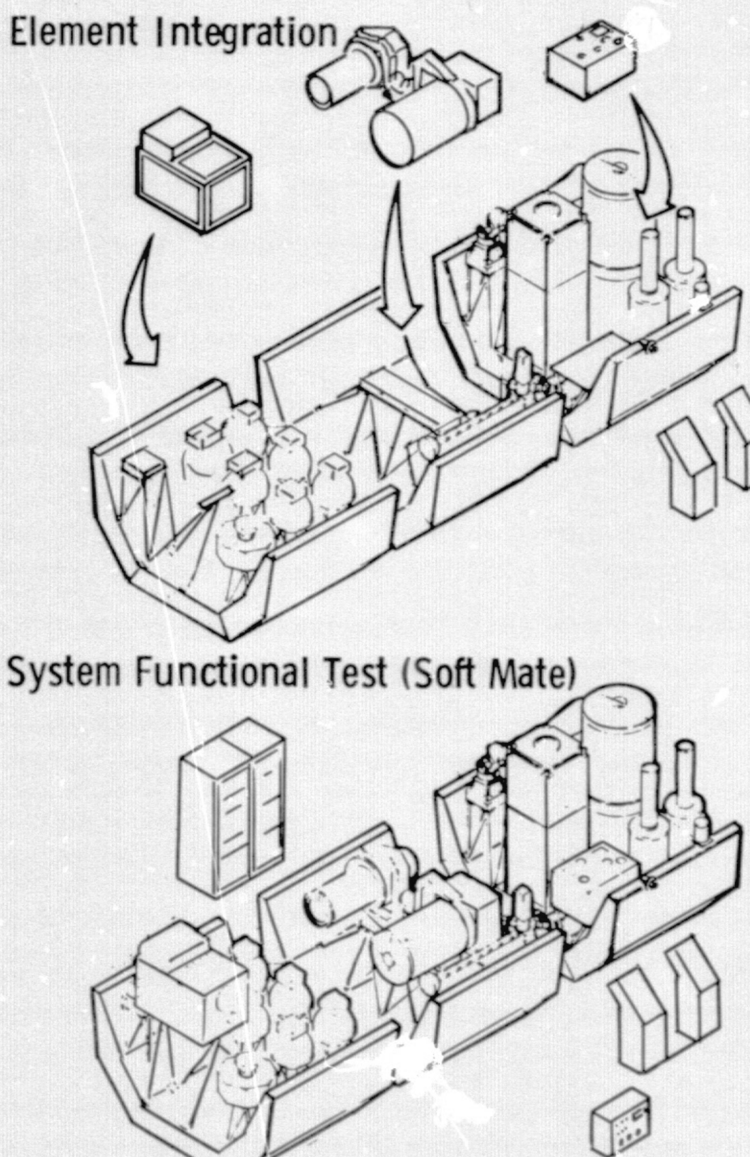
A. Level IV Integration--Payload

The primary objective of Level IV integration is to assemble the AMPS payload and perform systems level functional verification of the AMPS payload at the highest level possible to insure that all payload elements (i.e., instruments, FSE, PSS modules and Spacelab experiment racks) operate satisfactorily as an integrated payload; that no delay in the time critical Orbiter or Spacelab "on-line" activities will occur, and to establish a sufficient payload interface test and response data base that the payload systems health can be ascertained during the "on-line" interface checks.

The AMPS Level IV ground operations have been planned at the prime contractor's Denver facility, for initial payload assembly and system functional verification (Figure XI-2) and at the KSC PHF for final configuration assembly and functional verification, test, checkout and calibration of instruments (Figure XI-3) prior to delivery of the AMPS payload to the "on-line" Spacelab activities. The facility being planned for use by Martin Marietta is the existing high bay area clean room in the Denver Space Support building. Several existing facilities are being considered for use at KSC and these will be negotiated between the AMPS Project Office and the KSC Shuttle Project Office.

The following paragraphs describe the Level IV functional activities being planned for the initial payload assembly and verification at the prime contractor facility, and the final configuration and verification at the KSC PHF.

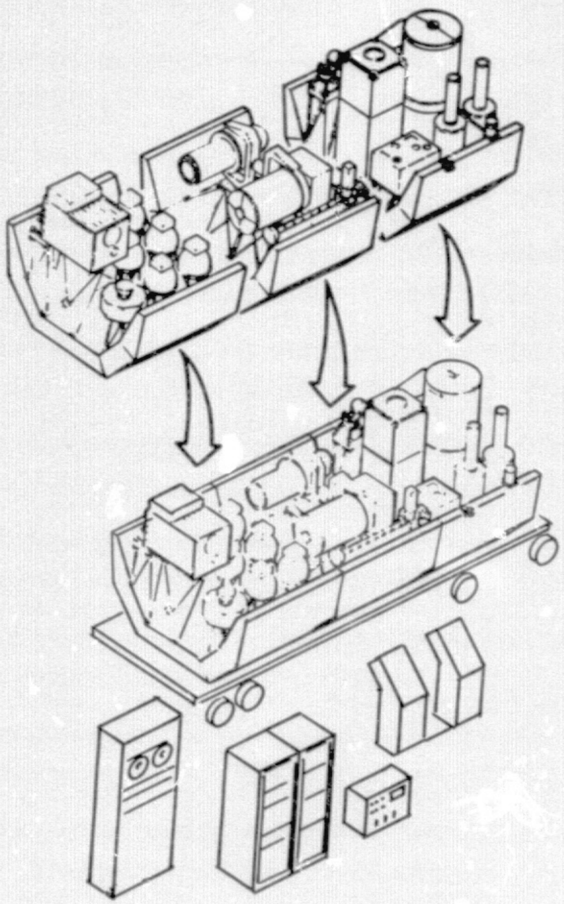
1. Initial Payload Assembly and Verification -- The initial AMPS assembly and verification will be accomplished as shown in Figure XI-2. This activity will be performed at the Martin Marietta Aerospace, Denver Division's Space Support building in the existing high bay area clean room. This clean room meets all the space, cleanliness, and support requirements (i.e., power and cranes) necessary to assemble and test a one, two, three, four, and five pallet payload. This facility has the ability to support two or more combinations of pallet trains at one time. The details of these facilities will be described in more detail in the GSE and facilities sections of this final report.



Integration of AMPS Elements
- Instruments
- FSE
- Pallets or Pallet Simulators
- Experiment Racks
- P/L PSS Modules

System Functional Verification
- Integrated/Soft-Mated Pallets
- Integrated Racks
- GSE - S/L Simulation
  - P/L PSS Module Mounting

Figure XI-2 Level IV Integration - Prime Contractor Facility



Integration of Outfitted Pallets
- Final Pallet Train
- I/F Verification

Integrated Functional Verification
- Pallet Train
- Experiment Racks
- P/L PSS Modules

Mount Support GSE
- Power
- Cryos

Figure XI-3 Level IV Integration - KSC AMPS Payload Handling Facility

The initial assembly activities will start with the receipt of the GFP units which include: instruments from the instrument development contractors; instruments from a Government agency; Spacelab components; flight support equipment (FSE) from either a contractor or Government agency; Spacelab components (i.e., pallets, experiment racks, thermal units...); and multi-use mission support equipment (MMSE). After these items have completed recieiving inspection they will complete interface verification tests and be ready for installation and assembly into or on the pallets with the prime contractor supplied FSE. The experiment racks and PSS module units will be assembled and each unit (i.e., individual pallets, experiment rack...) will complete system level interface verification tests. The pallets soft mated in a test fixture by electrically connecting the pallets together and the PSS modules and experiment racks will be mated with and connected to the test fixture and appropriate GSE. The associated GSE will simulate the Orbiter and Spacelab interfaces necessary to perform an AMPS payload functional verification test. This GSE will be described in the GSE and Facilities sections of this final report.

The AMPS functional verification tests will be described in detail in the test and verification section of this final report. In general they will include the development of parametric operational data which can be used to evaluate the performance of each instrument and FSE when the mission simulation tests and interface tests are accomplished in the succeeding Spacelab and Orbiter Levels III, II and I tests. This data will also be used to reverify payload compatibility and functional operation after the payload has been transported to KSC. After completion of all systems verification tests the pallets will be demated and the experiment racks and PSS modules will be removed from the test fixture and all flight units and selected GSE and test equipment will be prepared for shipment to KSC by either Government air or over the road.

2. Final Assembly and Verification -- The final assembly and verification of the AMPS payload at KSC prior to integration with the Spacelab and Orbiter will be accomplished as shown in Figure XI-3. This activity will be performed at the KSC-PHF which is yet to be identified from the various candidate facilities that already exist at KSC. This facility requirement will be discussed in more detail in the GSE and Facility section of the final report. In summary, the facility requirements for the PHF includes a clean room large enough to contain multiple pallet test fixtures, experiment racks, PSS module and associated GSE to interconnect all elements and simulate the Orbiter and Spacelab for functional verification tests.

The final assembly activities will start with receipt of the AMPS FSE and GSE (i.e., individual pallets, experiment racks and PSS module). After completion of the receiving inspection activities the flight element will be tested for interface compatibility and then assembled into the final flight configuration on the test fixture. This configuration consists of hard mating the pallet train, mechanically and electrically,

and installing the experiment racks and PSS modules in the test fixture. These elements and the associated GSE will simulate the Orbiter and Spacelab interfaces necessary to conduct payload and system functional verification tests required to establish high confidence that the AMPS payload can enter the time critical "on-line" Spacelab and Orbiter ground operations integration activities. Other functions which will be performed, as required, while the AMPS payload is in this "off-line" facility are, instrument checkout and alignment verification, charging of cryogenic thermal systems for instrument cooling during the mission, and mounting of any GSE on the pallet train which may be necessary to maintain a cryo charge on a system during subsequent ground operations, or GSE necessary to provide instrument stimulus for subsequent ground operations, tests and checkout functions. These verification tests will be described in more detail in the System Test section of this final report.

Upon completion of this phase of the AMPS payload "off-line" activities, the mated pallet train, experiment racks and PSS module will be transported from the AMPS-PHF to the SPF in the O&C Building at KSC for "on-line" Spacelab Level III and II integration.

This completes the ground operations activities for which the AMPS project has the prime responsibility. All activities for Levels III, II, I, and launch preparation are the on-line function and the primary responsibility of the KSC and the associated project such as the Orbiter or Spacelab organizations. The associated schedule for completion of these activities is shown in Figure XI-4.

B. Level III/II Integration--Spacelab

The primary objectives of the Spacelab "on-line" Level III and II integration activities are to assemble the payload elements into an AMPS Spacelab Payload and to functionally verify that the integrated Spacelab payload is operating satisfactorily and is ready to proceed with the Orbiter "on-line" Level I integration activities.

The Spacelab Level III and II integration activities are presently being planned to occur at the SPF in the KSC O&C building. All necessary support fixtures, GSE, and facility requirements to perform these integration activities will be provided and the AMPS payload can be integrated into a complete AMPS Spacelab payload with only minimum GSE and personnel support from the AMPS project being required. The Spacelab Level III and II ground operations are shown in Figure XI-5.

The following paragraphs describe the Level III and II activities being planned by the NASA for integration of payloads into the Spacelab. Level III is identified as Spacelab payload assembly and Level II is identified as Spacelab payload integration verification.

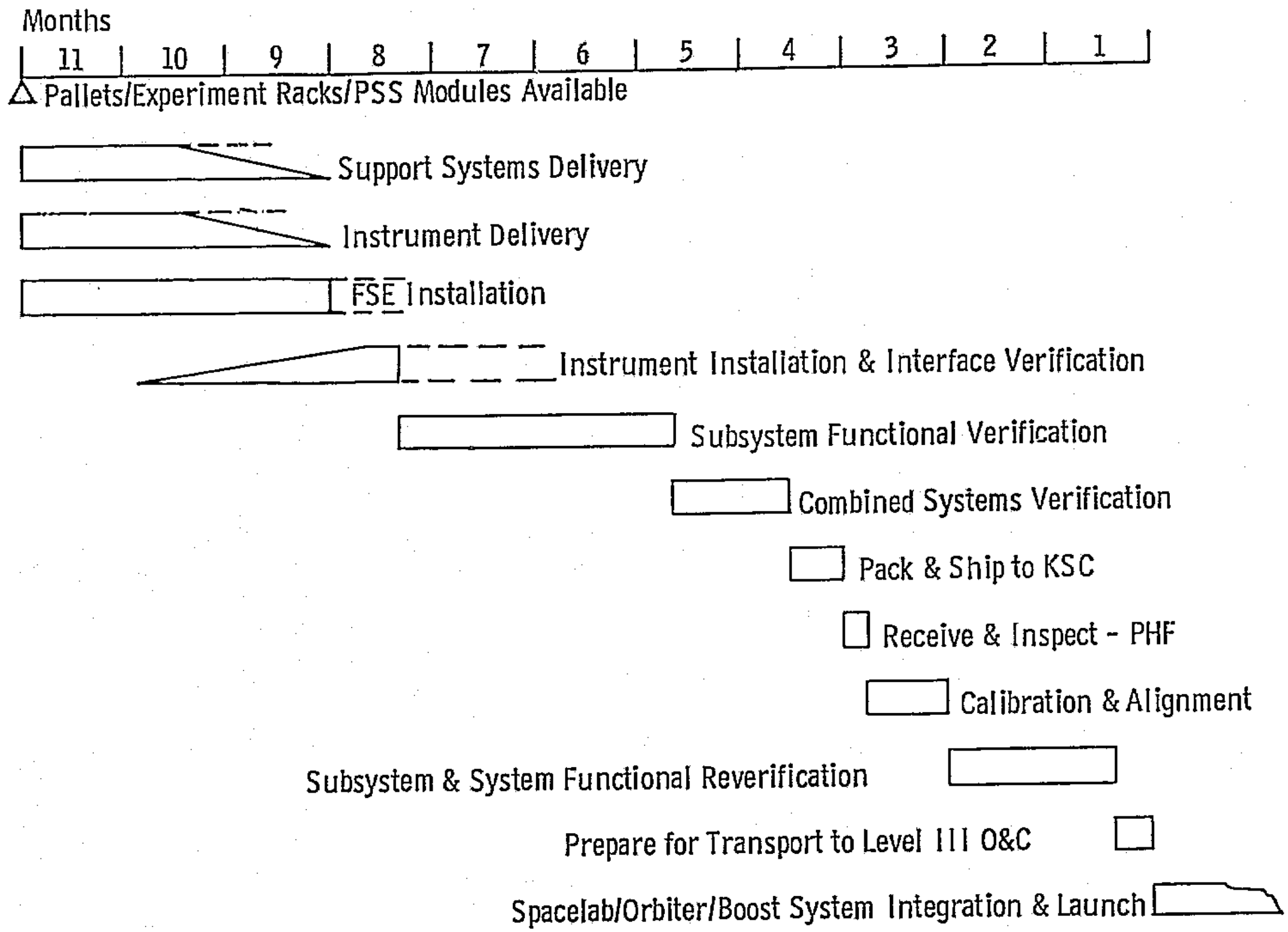
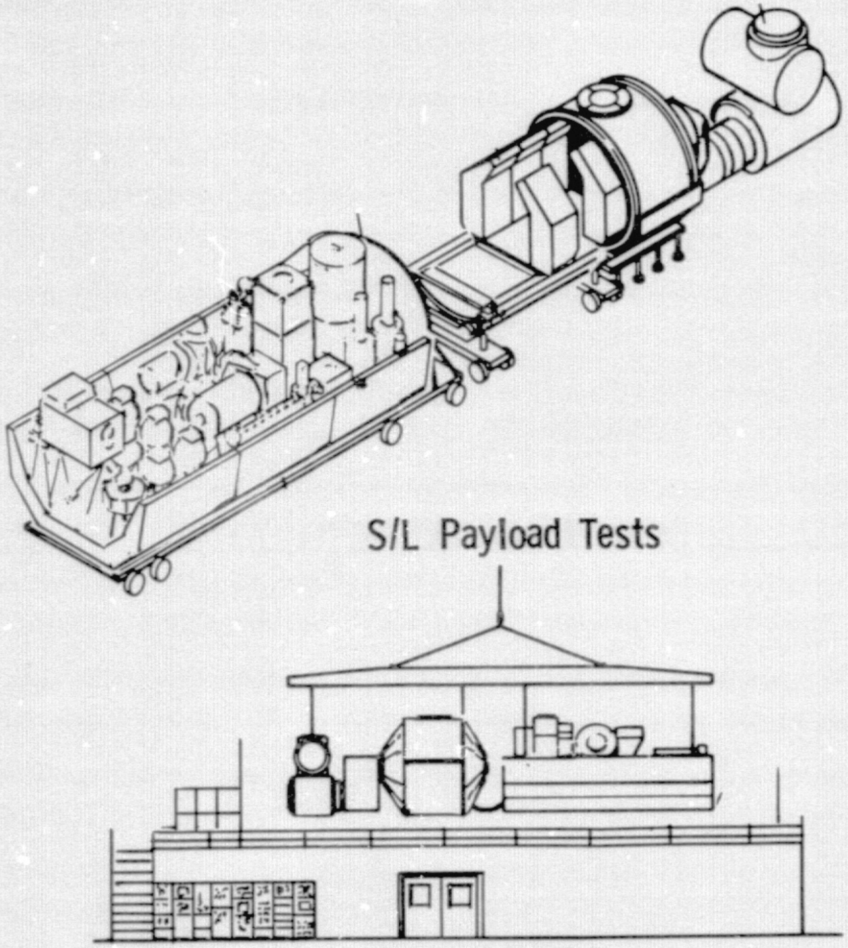


Figure XI-4 AMPS Level IV Assembly and Checkout Schedule



Integration of AMPS and S/L Elements
- Pallet Train
- Experiment Racks
- Pressure Module

Integrated P/L Tests (CITE)
- Functional I/F Verification
- Simulated Mission Sequence

Install Safety-Critical Items
- Payload Ordnance
- Chemical Release Canisters

Facility Location
KSC, O&C

Figure XI-5 Level III/II Integration

1. Level III Spacelab Payload Assembly -- The AMPS Spacelab payload assembly will start with the receipt of the AMPS payload elements from the Level IV final integration facility, KSC-PHF. After completion of the receiving inspection activities the AMPS payload elements (i.e., pallet train, experiment racks, PSS modules, and selected GSE) are installed in the Spacelab integration and checkout fixture for physical assembly of the Spacelab pressurized module elements, and AMPS payload elements into a total AMPS Spacelab payload in preparation of the Level II functional verification tests.

2. Level II Spacelab Payload Verification -- The AMPS Spacelab Payload interfaces and operations will be verified by conducting; system interface verification, subsystem functional checkout, payload functional verification, and simulate mission sequence tests. These test and checkout activities will be performed at the KSC-SPF located in the NASA O&C building using the assembly integration and checkout fixture and the Automatic Test Equipment (ATE) to make up the test and integration stand.

During these two integration activities the KSC Spacelab Operational Turnaround Allocation schedule dated 16 April 1976 and summarized in Figure XI-6 identified only 46 hours of test time when electrical power would be available for payload tests. This amount of functional verification and checkout under power would severely restrict the depth and completeness of flight readiness verification which could be accomplished during these "on-line" ground operations activities. As a result of this limitation major AMPS payload operations confidence must be achieved during the "off-line" Level IV activities in the AMPS-PHF.

Upon completion of these Spacelab payload integration activities the combined AMPS Spacelab payload will be transported to the Orbiter Processing Facility (OPF) for integration into the Shuttle Orbiter payload bay.

C. Level I Integration--Orbiter

The primary objectives of the Orbiter "on-line" Level I integration activity are to mate the AMPS Spacelab payload with the Orbiter, and to ready the Orbiter and payload for the succeeding launch preparations. These integration activities are accomplished in the OPF.

The AMPS Spacelab payload and Orbiter integration starts with receiving the payload then progresses to installation into the Orbiter bay, verification of the payload interfaces, final preparation for launch and closeout of the payload bay. Upon satisfactorily completion of Orbiter integration activities, the Orbiter with its AMPS Spacelab payload is transported to the vertical assembly building (VAB). The major activities are shown in Figure XI-6.

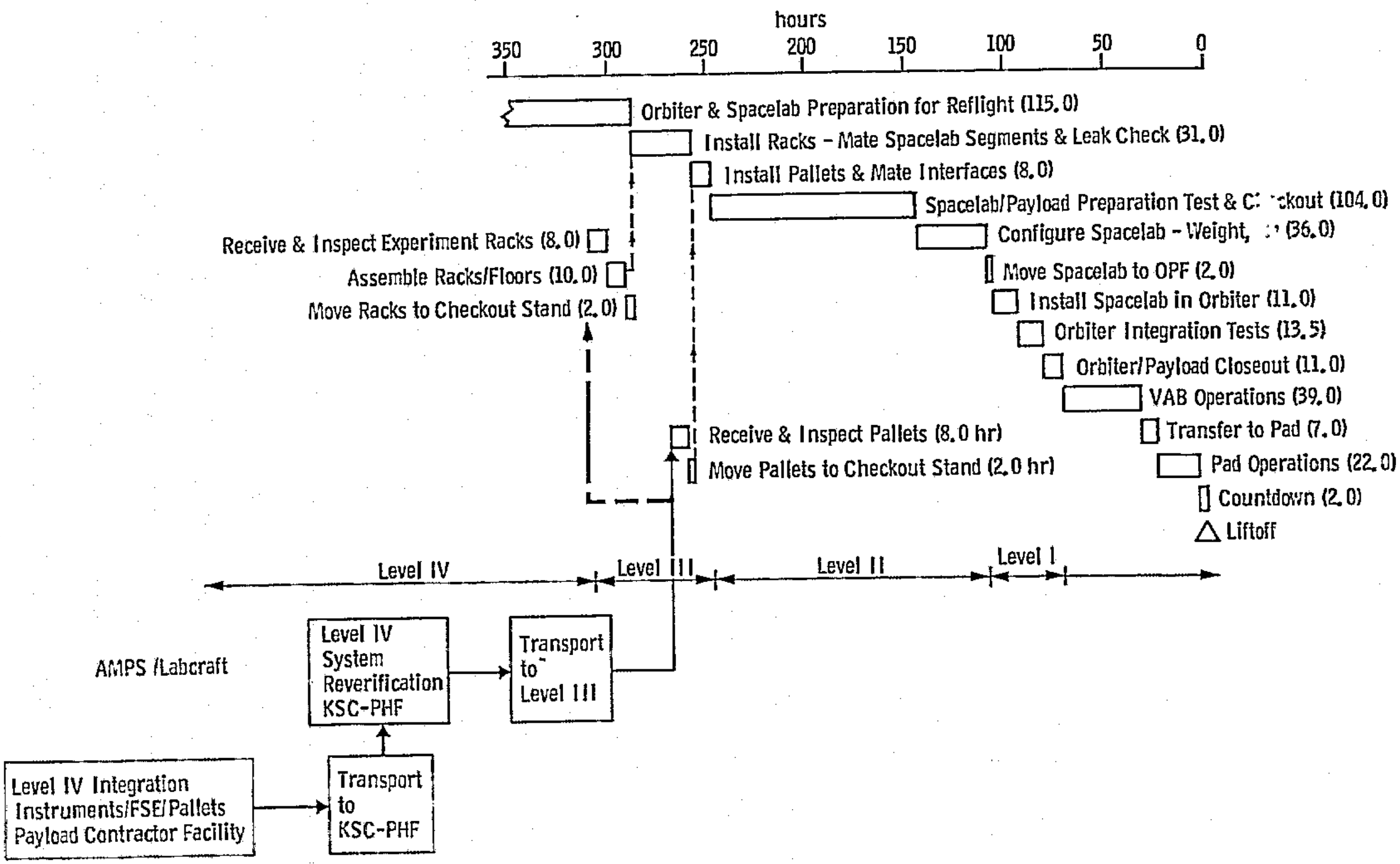


Figure XI-6 AMPS/STS Ground Operations Summary Schedule

D. Launch Preparations and Launch

The major launch preparations include moving the Orbiter and installed payload to the VAB; erecting and mating the Orbiter with the STS booster systems; towing the Shuttle flight system to the launch pad; completing the final launch activities at the pad; and launching the Shuttle vehicle. During these activities the payload is in the Orbiter bay with the doors closed and no payload access is permitted except after the Payload Changeout Room (PCR) is in place around the payload bay on the launch pad. During the time this PCR is in place the Shuttle Orbiter payload bay doors can be opened, if required, and access gained to the payload for minor activities requiring no power. These activities can be such things as removal of cryogenic maintenance GSE, or removal of protective covers. This time period is approximately four hours long and occurs at approximately eight hours prior to lift-off.

E. Landing and Demating

The landing and demating activities are generally payload hands-off until the Orbiter is returned to the OPF which occurs within the first couple of hours after landing. The exception is of course that some items from the Spacelab, such as recorder tapes, could be removed from the Spacelab while in orbit and stowed in the Orbiter cabin, then taken from the Orbiter by the crew.

Some critical AMPS payload items can be removed from the Orbiter bay in the OPF after the payload bay doors are open and the access GSE installed but generally access to the payload should not be planned until after the AMPS Spacelab payload has been removed from the Orbiter bay and transported to the SPF in the O&C building.

The Spacelab payload demating activities take place in the SPF starting at approximately twenty hours after landing. The Spacelab pressure module is demated and the AMPS experiment racks removed and the pallet train is demated. The AMPS payload elements are then transported to the AMPS-PHF for maintenance and refurbishment.

F. Maintenance and Refurbishment

All AMPS maintenance and refurbishment activities are either initiated from or accomplished in the AMPS KSC-PHF. After receipt of the AMPS payload the payload instruments and FSE will be prepared and updated for the next flight. The baseline plan will be for the instruments and FSE to be updated at the PHF if possible but if major modifications or repairs must be made then that equipment will either be returned to the contractor's facility or GSFC for action.

The next flight preparations will continue at the KSC-PHF for all AMPS payload elements except for the alternative to the baseline plan

described above and any newly outfitted pallets, which will be received from the prime contractors Level IV initial integration facility. These new pallet configurated payload elements will then be integrated into the final payload and the ground operations will continue as previously described. Those elements requiring storage will be stored at the PHF until their reuse is required; if however, the element will not be reused it will be sent to GSFC for permanent storage.

G. Alternative Approaches

Alternative approaches to integration were studied which involved the availability of Spacelab pallets. Specifically these included pallets being available for 22½ days at the contractor's Level IV integration facility; pallets only available for 22½ days at the KSC PHF; and multiple discipline payloads where another NASA center is responsible for a major element of the payload. These alternative availabilities of the Spacelab pallets do not change the definitions and activities described above for the AMPS payload ground operations, however, in some cases, as described in the following paragraphs, additional activities must be planned to take place at one or both of the Level IV "off-line" integration facilities. The following paragraphs describe the impacts of these.

1. Pallets Available at the Prime Contractor's Facility -- At the request of the GSFC AMPS Project Office an alternate approach to payload assembly was analyzed which required that the Spacelab pallets would be available at the prime contractor's facility for 22½ days prior to shipment of the assembled AMPS pallets back to KSC. Therefore during the 22½ day period the AMPS flight instruments and FSE must be assembled on the pallets and the payload operation functionally verified. In order to accomplish the initial assembly and verification activities described in the baseline Level IV processes the concept derived required construction of a pallet interface simulator (Figure XI-7). The pallet interface simulator would be used as a tool to assemble the AMPS instruments and FSE on and a test bed from which all interface and functional verification tests to be conducted. After receipt of the Spacelab flight pallets the instrument and FSE groupings would be transferred from the pallet interface simulator to the actual flight pallets and functional interface testing completed to verify interface compatibility. The assembled and tested AMPS payload would then follow the normal ground operations flow. The pallet simulator to flight pallet transfer schedule is shown in Figure XI-8. The total schedule impact of transferring from the simulator structure to the actual flight pallets is an additional 14 days.

2. Pallets Available at the KSC-PHF -- The second pallet availability constraint studied was with respect to having the Spacelab pallets available at the KSC-AMPS PHF for only 22½ days prior to transfer into the "on-line" Level III integration activities. In this case the pallet simulator shown in Figure XI-9 would be transportable and

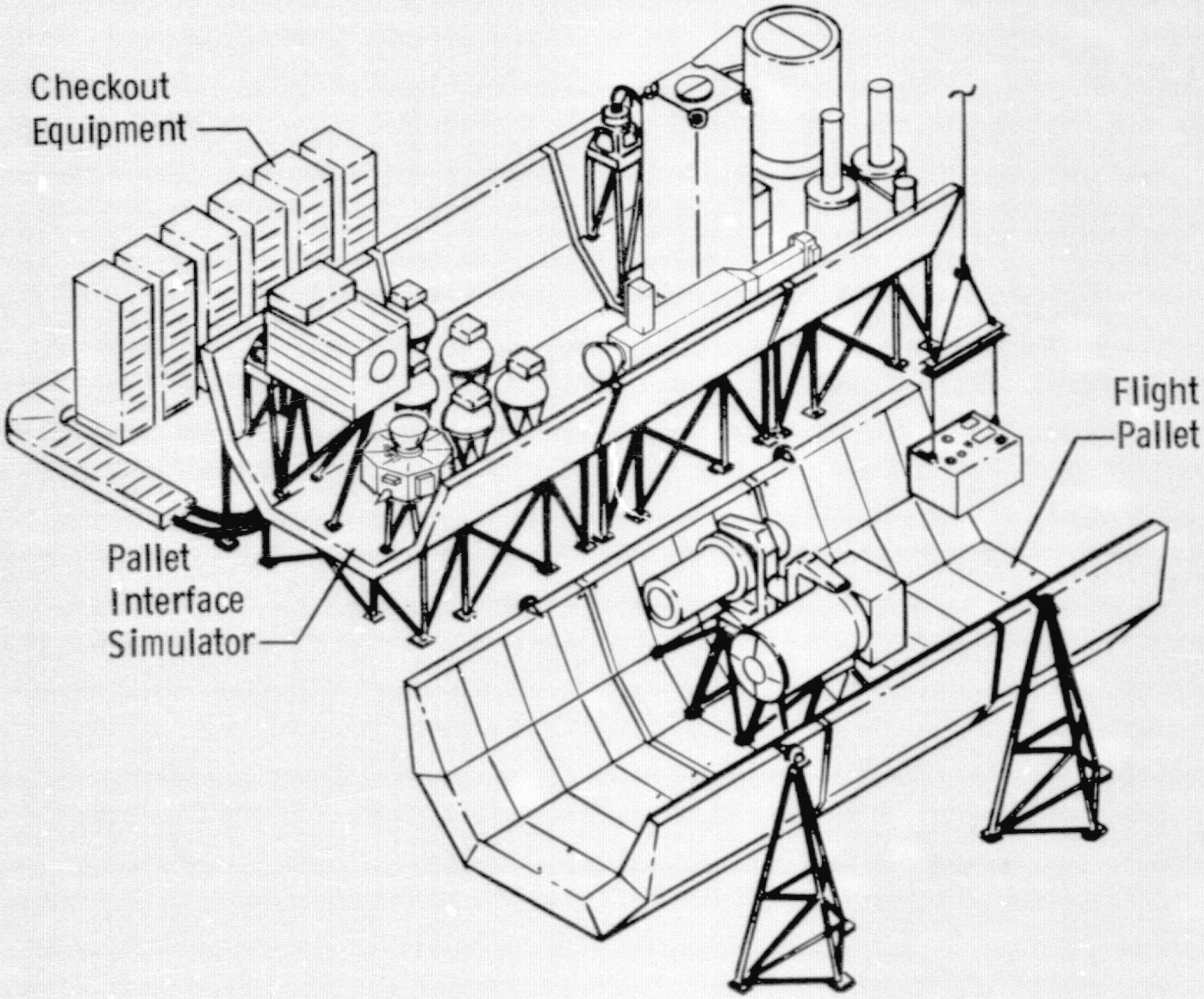


Figure XI-7 Pallet Interface Simulator

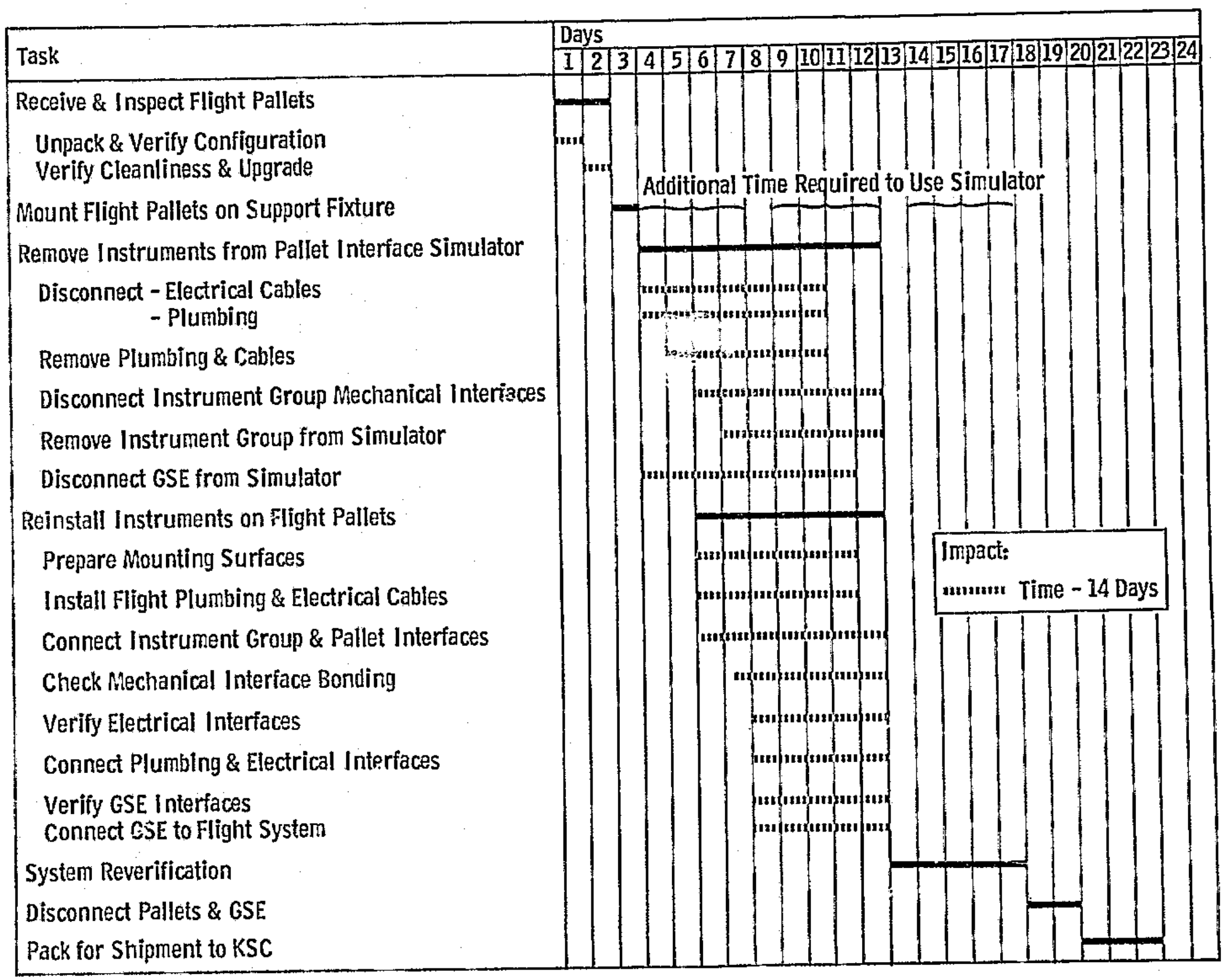


Figure XI-8 Pallet Simulator to Flight Pallet Transfer Schedule

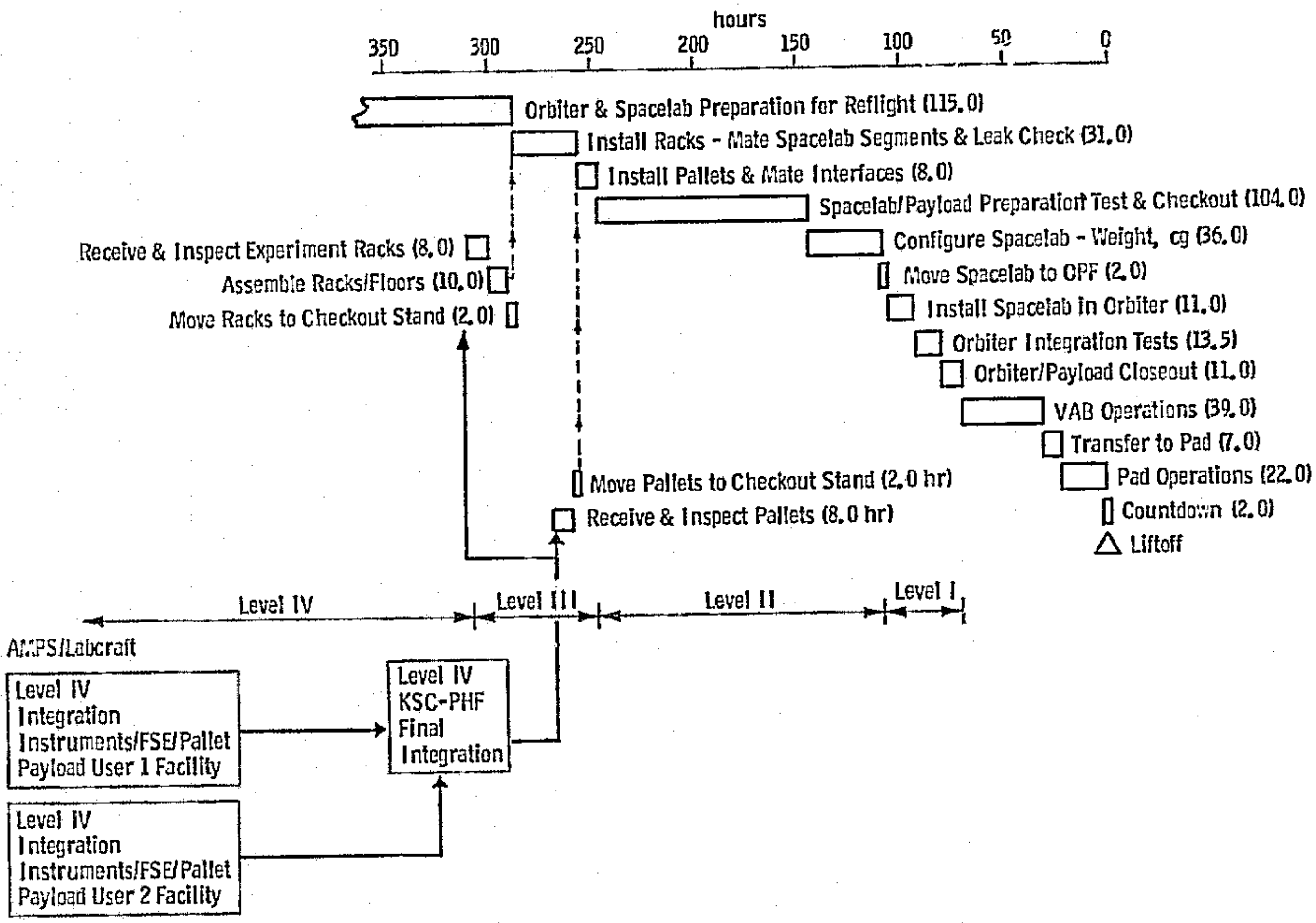


Figure XI-9 Multidiscipline Payload Integration Schedule

the AMPS payload instruments and FSE would be assembled and tested on the pallet simulator at the Level IV initial assembly and verification location (Prime Contractor's Facility) then transferred t(the KSC-PHF for final Level IV assembly and test which would include the transfer of instrument and FSE groups from the pallet simulator to the Spacelab flight pallets prior to completion of the Level IV activities. The schedule impact of 14 days as shown in Figure XI-8 would also apply at this facility.

3. <u>Multiple Discipline Payloads</u> -- The approach taken with multiple discipline payloads is essentially the same as that identified for the baseline approach. As shown in the multidiscipline payload integration schedule, Figure XI-9, the Level IV initial assembly and test would be accomplished at both payload users integration facility and then transferred to the KSC Labcraft PHF for Level IV final assembly and verification before entering the baseline Spacelab and Orbiter "on-line" activity sequence.

XII Mission Operations

The mission operations support plan for AMPS flights is based on an understanding of the elements, both spaceborne and ground, that make up the STS operations approach; establishing the significant payload functions needed to support the operation of the mission, including the flight planning operations; defining the responsibilities of the participants in this support role; and establishing and defining the training requirements for the crew relative to their participation in these payload mission operations.

A. Elements of Mission Operations

Figure XII-1 depicts the various elements required in the operation of an STS, and hence, an AMPS mission. The data generated onboard the orbiter, within the Spacelab and by the payload is programmed to be returned via the TDRS. Commands will also be transmitted to the orbiter, Spacelab and the payload via this same system.

The downlink data is divided into two groups. The first consists of low rate operational data (192 Kbps) from the orbiter required for JSC Mission Control Center (MCC) management of the overall mission. Low rate payload data up to 64 Kbps, consisting of either housekeeping or science data, can be interleaved into this data stream. The second group handles instrument housekeeping and science data in digital format at rates up to 50 Mbps as well as video or analog data up to a 4.5 MHz bandwidth. Both groups of data are received at the TDRST and routed directly to users without processing or recording.

The JSC MCC has been assigned overall mission management for STS missions. The 192 Kbps data stream is routed, via landlines, to the MCC where it is processed for real time or near real time display, control processing and recording for post mission evaluation. This data provides subsystem status information as to the health and welfare of the STS and monitors any payload instrument parameters that could affect the safety of the crew, the spacecraft or the mission. Mission contingency and reprogramming decisions are made at the MCC and commands will be generated and transmitted via the TDRS to modify operations.

Payload control and monitoring, because of the highly complex nature and variety of scientific instrumentation, is considered as the responsibility of the Payload Operations Center (POC) and will be performed at the Payload Operations Control Center (POCC). The expertise required to evaluate instrument data and reprogram experiments will be supplied by payload operations personnel who have been trained in the operation and data analysis requirements and aspects of the specific instruments.

Science data, together with instrument housekeeping data, is therefore routed to the POCC from the TDRST for these specialists, where it is processed either for real time or near real time display

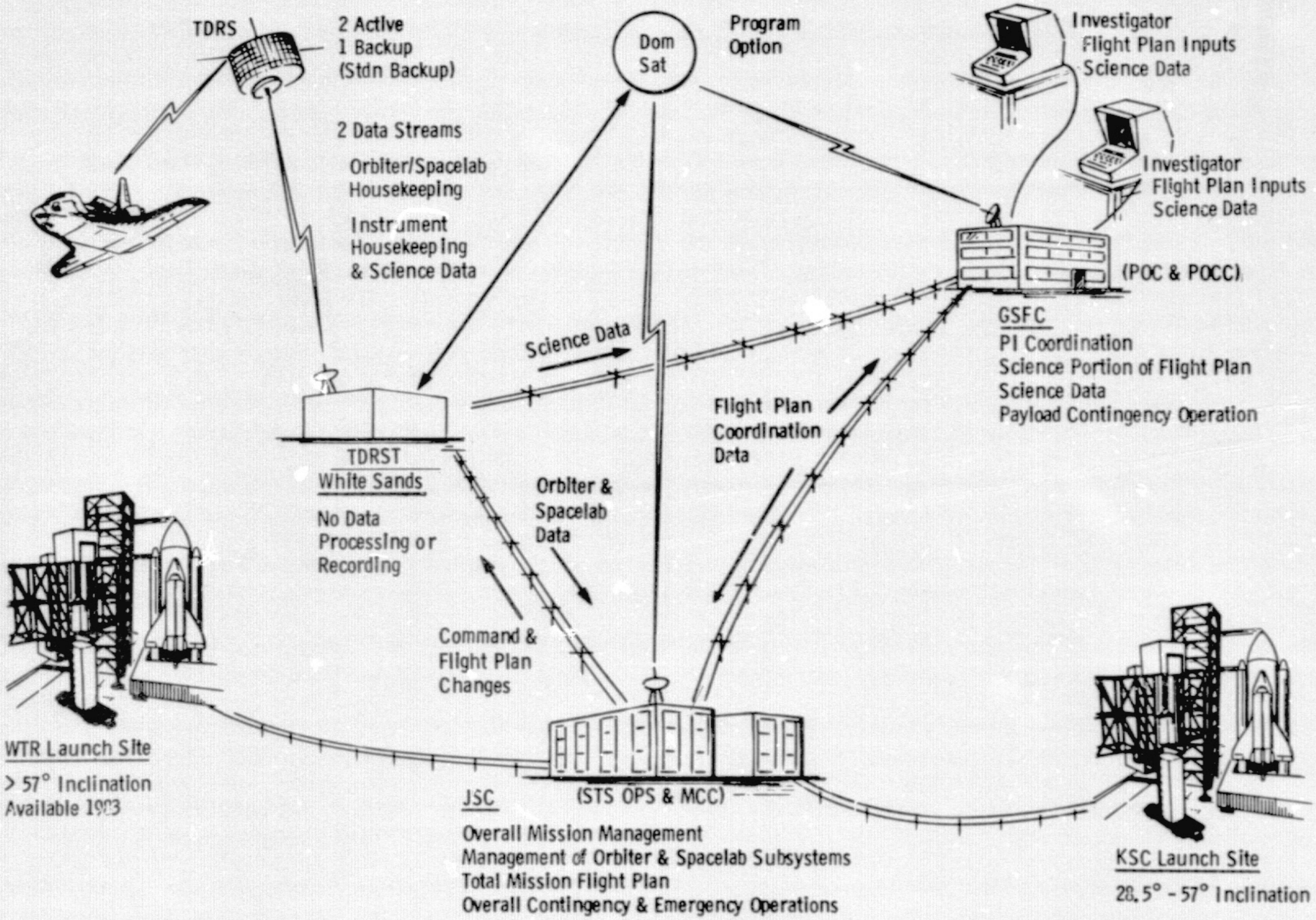


Figure XII-1 Elements of Mission Operations

and it is recorded for post mission evaluation. A capability to reprogram instrument operations and generate the commands required to modify the mission sequence is also provided and these commands are routed through the MCC prior to transmission by the TDRS in order to insure that crew safety has not been compromised. Scientific data rates for AMPS investigations indicate a need to employ the DOMSAT for relay transmission from TDRST to the GSFC POCC because of the 1.3 Mbps limitation on available landlines.

The location of the POCC is based on assigned responsibility for payload definition and procurement and the need to integrate the scientist into payload operations. During the early phases of the AMPS design, including the instruments anticipated for AMPS use, the development of interfaces and software for use with the Spacelab and ground checkout computers will be accommodated through communication terminals connecting to the payload operations center. These terminals can also be used to exercise end-to-end operations techniques with the POCC early enough in the program to allow sufficient time for corrections. It is envisioned that the communication tie-in with the POCC will be established as soon as possible after contracting for an instrument or FSE. In addition to software and interface development, this capability will support optimization of ground versus airborne instrument control by providing a total system simulation to exercise experiment performance and reprogramming procedures.

B. Payload Operations Functions

A primary AMPS program goal is the enhancement of the collection and evaluation of the scientific data collected during the AMPS flights. The critical functions that are necessary to provide this enhancement are summarized in Figure XII-2. As noted, the orbiter crew and payload specialist functions are recognized as an integral part of the mission tasks and the design of the laboratory is based on providing them the capability to perform these functions.

The ground functions required to support overall mission performance and to control the orbiter within the payload requirements are those supplied by the MCC. Figure XII-2 lists types of tasks that are foreseen for any Spacelab payload, specific examples of which are orbiter orientation planning to fill payload needs; electrical energy monitoring and resource control; mission command sequence generation/implementation; and integration of payload command sequences. These tasks provide a basic approach to the control of any mission and are tailored to fit specific program requirements identified by mission science teams.

The ground functions required to support experiment operations (as listed in Figure XII-2) are the responsibility of the POCC. Ground based support for the payload specialist is provided in terms of real time monitoring of critical data, evaluation of experiment results and replanning of the mission to enhance science data production.

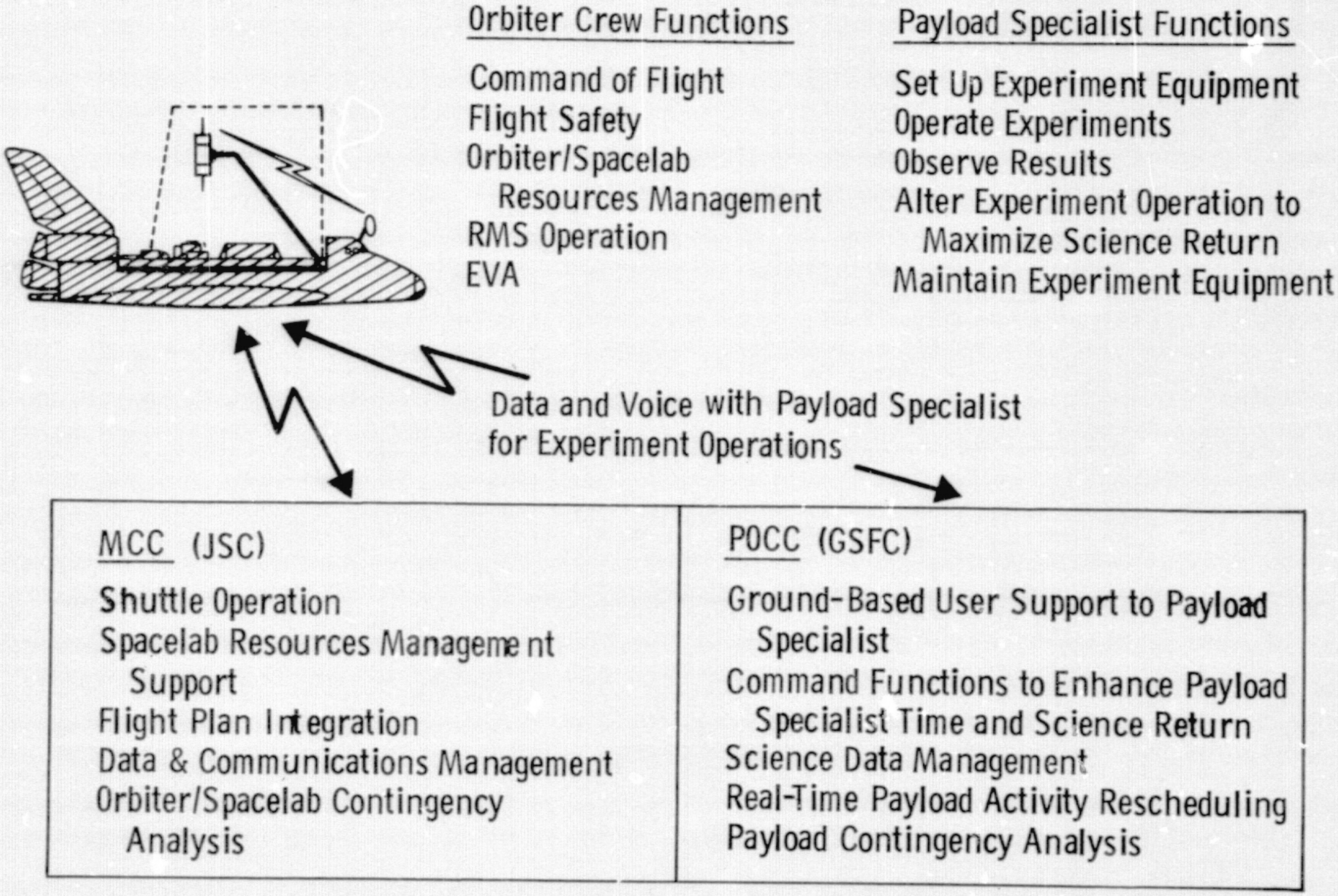


Figure XII-2 Mission Operations Functions

A command sequence generation capability is provided which allows reprogramming experiment sequencing and optimizing the use of the payload specialists time in performing necessary manual functions. Science data management is provided in the form of real time data monitoring, processing and tagging of post mission evaluation data. Tie-in with principal investigators is envisioned on a real time basis to enhance data evaluation and reprogramming when necessary.

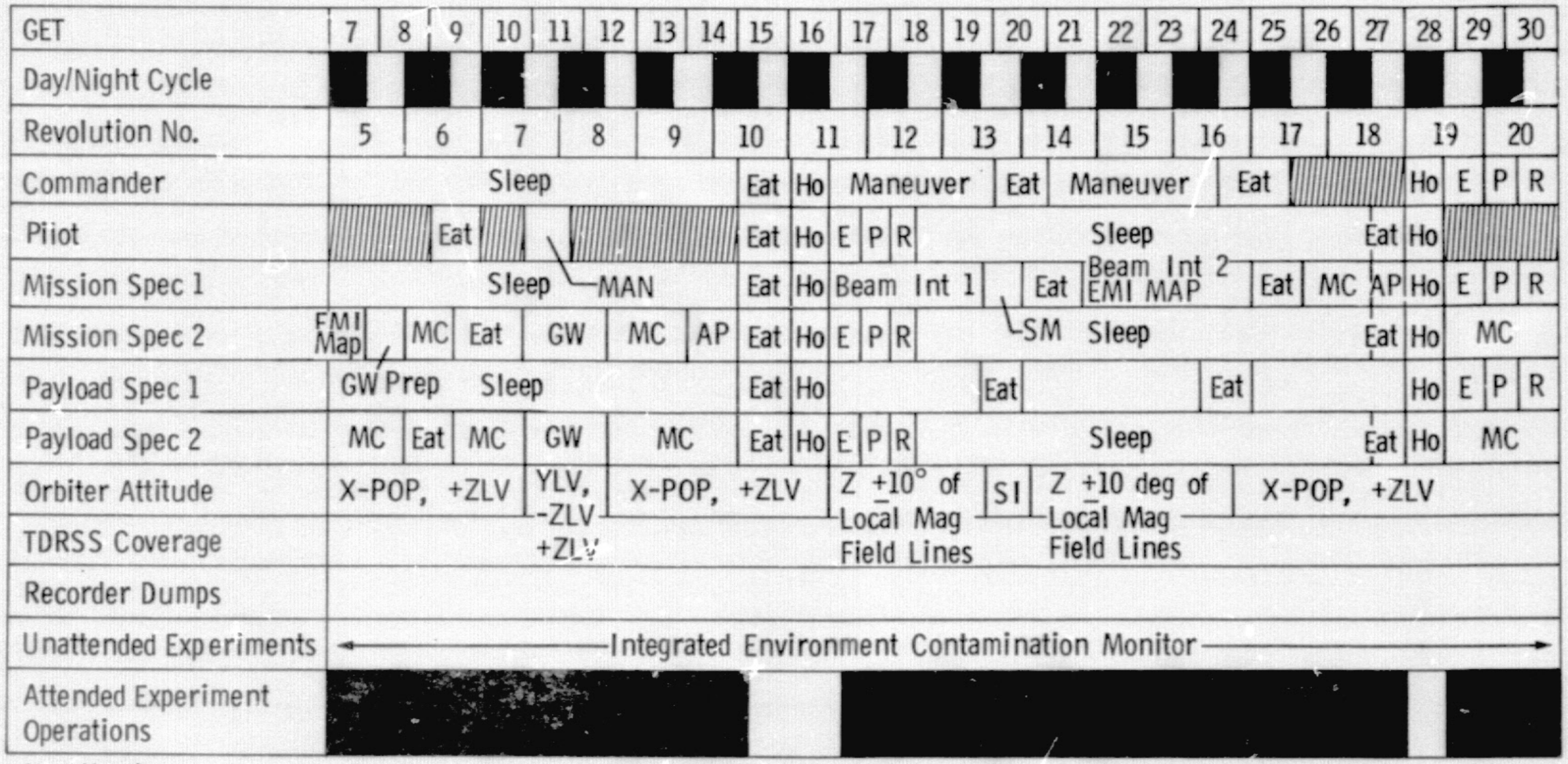
Real time payload activity replanning and contingency analysis will provide a team of experts and a computation capability that will be available to the payload specialist when needed to supplement his onboard replanning capability. The overall design of the laboratory and its ground support must remain sufficiently flexible to allow for optimization of ground versus spaceborne control of experiment sequences.

C. Flight Planning

A significant activity relative to optimizing the role of the crew during payload operations, and hence the scientific data accrued therefrom, is the flight planning activity that is developed in the early stages of Phase C/D and subsequently implemented as real time support during the conduct of the AMPS mission.

The early phase activity consists of defining and developing the ground and onboard automated flight planning tools. Specifically, this would consist of the computer programs for timeline generation, experiment opportunities, initial data base development and data file indexing. A determination will be made as to whether manual or automated and whether ground or onboard modes are the most desirable. Early emphasis will be directed toward the determination of the crew's role in flight planning to develop and efficient interface between ground and crew.

When the mission objectives and requirements have been adequately refined and priorities and other specific scheduling criteria have been defined, an efficient crew schedule will be developed by trading crew, systems (both vehicle and system) and trajectory constraints to optimize mission achievement. The basic trajectory timeline will be overlaid with the required crew and system constraints, i.e., crew work cycle, exercise, meals, systems housekeeping and vehicle maintenance. With these basic required activities scheduled, specific crew activities can then be inserted based upon detailed mission requirements, thus maximizing mission accomplishment. Time or trajectory critical activities will be scheduled first and the basic timeline schedule will then be modified as necessary to reflect these critical activities. Priorities, temporal relationships, sequence, number of performances, data retrieval and specific experiment operational objectives will be included as appropriate. A sample flight plan timeline for flight 1, day 1, mission hours 7 through 30 is shown in Figure XII-3.



Ho Handover E Exercise AP Activity Planning GW Gravity Wave

P Personal Hygiene R Rest and Relax MC Minor Constituents MAN Maneuver

SM Solar Monitor ▨ Unscheduled Time

Hours 1-6 Boost/Insertion, Doors Open, Orbiter/Spacelab/Experiment Activation & Checkout

Figure XII-3 Sample Flight Plan Timeline

Once the mission has begun, support will continue to be provided to the appropriate members of the GSFC POCC team in maintaining the optimization of the flight plan so that mission results are similarly optimized. As onboard problems arise that affect the completion of the day's activities as they have been scheduled (or as they affect a later day's planning activity) real time changes to these timelines can and will be made that will consider the various priorities, constraints and so on, so as to provide the appropriate GSFC POCC personnel the adequate options of reprogrammed activities that they would want to consider to implement as replacement activities.

Representative detailed constraint categories that we will consider during this real time flight planning change activity (as well as during the initial generation) will include:

1) Vehicle/Ground -- attitude, communications, network coverage, system capabilities, data management, consumables and experiment hardware;

2) Trajectory -- ground targets, solar lighting, celestial targets and maneuvers required for target acquisition;

3) Crew -- time available, crew specialties, safety and health.

D. Mission Operations Responsibilities

The responsibility for mission operations is divided such that the JSC MCC has responsibility for the orbiter and the GSFC POCC is responsible for the AMPS payload. The results of the preliminary evaluations of the operations responsibilities is depicted in Figure XII-4.

The MCC lead responsibility is vested in the Flight Director who has overall responsibility for mission accomplishment and who interfaces with the Payload Operations Director through his Payload Officer. The flight activity planning and communications control will be integrated with the payload requirements through these personnel.

The Payload Operations Officer has the responsibility for the overall conduct of the scientific portion of the mission. He reports to the Payload Operations Director who is responsible for the overall GSFC POCC activity, and he is supported by the Mission Scientist and his staff who will be responsible for decisions affecting specific instrument use, interexperiment priorities and experiment replanning. They also evaluate the science data and direct mission changes to enhance the results.

The Payload Activity Planning Officer is responsible for the detailed scheduling of all sequences affecting payload operations.

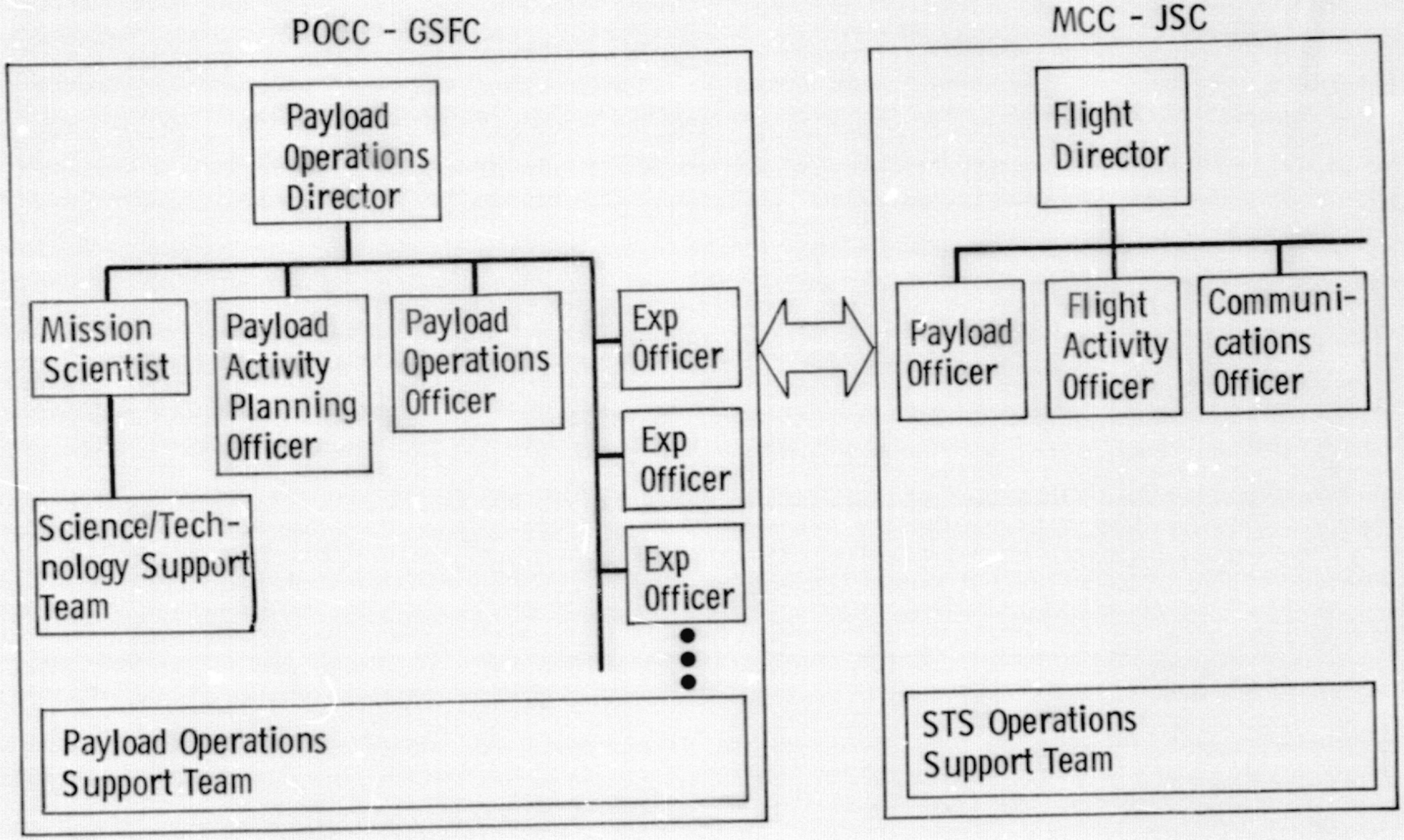


Figure XII-4 Mission Operations Responsibilities

The Payload Operations Officer is also responsible for integrating both scientific and laboratory support equipment operations in terms of resource management, time allocated for a given investigation, contingency replanning, hardware usage decisions, and so on. He will also be responsible for day to day interfacing with the MCC Payload Officer to resolve differences between mission and payload operations.

The Experiment Officers have the responsibility to assure proper conduct of the specific investigations and to evaluate instrument operation. They will be well versed in all phases of experiment operation, including each individual instrument, and will consult with the Science Staff in the evaluation of results and reprogramming during the mission.

Both control centers provide operations support teams for detailed analysis of subsystems and instrument performance. They will evaluate housekeeping data, flag problem areas, develop workarounds, determine maintenance approaches and generally provide technical support for the operations team.

Martin Marietta will begin mission analysis for Labcraft missions at contract go-ahead by updating preliminary analyses using new requirements from the selected AMPS instrument/experiment contractors. Initial mission profile requirements including altitude, attitude, inclination, duration and launch time preferences will be determined. Preliminary inputs will be coordinated with JSC-MCC, and GSFC-POCC representatives to determine compatibility of mission and crew planning parameters with STS flight and command system capabilities. Prior to AMPS PDR, tradeoffs of AMPS mission objectives and constraints will be made with STS-Spacelab and projected AMPS FSE systems capabilities to establish operational requirements on systems designs or modifications. Long lead software/hardware impacts on POCC or MCC will be identified and preliminary requirements coordination established. By AMPS CDR, all FSE and AMPS instrument configurations will be compatible with the recommended mission profiles and preliminary payload flight planning. Outputs from preliminary FMEA and hazards analysis will be reviewed to identify contingency or alternative operational modes to maximize future mission success. Mission requirements updating will include consumables, timelined payload viewing measurements, experiments and antenna pointing, instrument thermal constraints, and subsatellite launch, near Orbiter control and remote operating command, control and viewing requirements. Recommendations for minimization of instrument contamination by timely control of spacecraft vents and dumps will also be identified and integrated into payload flight plans.

Preliminary payload operational procedures and sequences will be developed and utilized as much as possible during Level IV test and checkout and expanded as AMPS hardware proceeds through Levels III and II at KSC. Flight and ground crew familiarity with realistic mission procedures will be increased as test and checkout proceeds

up to final integrated mission simulations at KSC Level III-II in which the entire flight crew, the AMPS/Spacelab flight hardware, software and supporting mission simulation equipment and STS/Spacelab and AMPS flight controllers are joined in a fully realistic integrated test of a simulated AMPS mission. Members of the GSFC/MMC/experimenter payload operations team which was initiated at CDR, and supported Level IV, III and II testing, proceed to GSFC-POCC and JSC-MCC for final in-place training during the mission simulations and remain on-station during the entire pre-launch and flight operations through recovery. They will participate in quick-look data reviews as required by GSFC and return to support post-flight data processing and mission completion.

E. Crew Training

The complex scientific nature of the AMPS missions, along with the limited availability of crew members, imposes a significant requirement for cross training to provide overlap for task performance.

A preliminary training requirements analysis including evaluation of the types and numbers of instruments, available mission time, daily activity sequences, support equipment, operation requirements and other related mission parameters has resulted in a recommendation of a minimum training time allotment as shown in Figure XII-5. This Figure lists for each crewman both the orbiter (JSC provided) and the AMPS payload related training requirements (to be provided by GSFC).

The Figure recommends that each crewmember be given selected training beyond his specific area of responsibility so that he can support other phases of the mission should the need arise. This analysis recognized the need for backup operators for each payload task and that additional training of more than one crewman may well be required in the operation of specific complex instruments or FSE.

The training approach and related simulators identified to support AMPS scientific payload training are as follows:

1) <u>Classroom</u> -- Formal classroom briefings will familiarize the flight crew with overall mission objectives, basic science objectives and techniques, experiment descriptions, instrument and special FSE operating techniques, and simultaneous orbiter control tasks. Control and display panel layouts and equipment operating data will be covered as part of this training. Methodology of interfacing with ground science teams will also be described.

2) <u>Part Task Trainer</u> -- A simulation of the Spacelab Command and Data Management System (CDMS) will provide specific training for the operation of each specific experiment. This part task trainer supplements the Spacelab simulator, located at JSC, which has multiple use requirements to